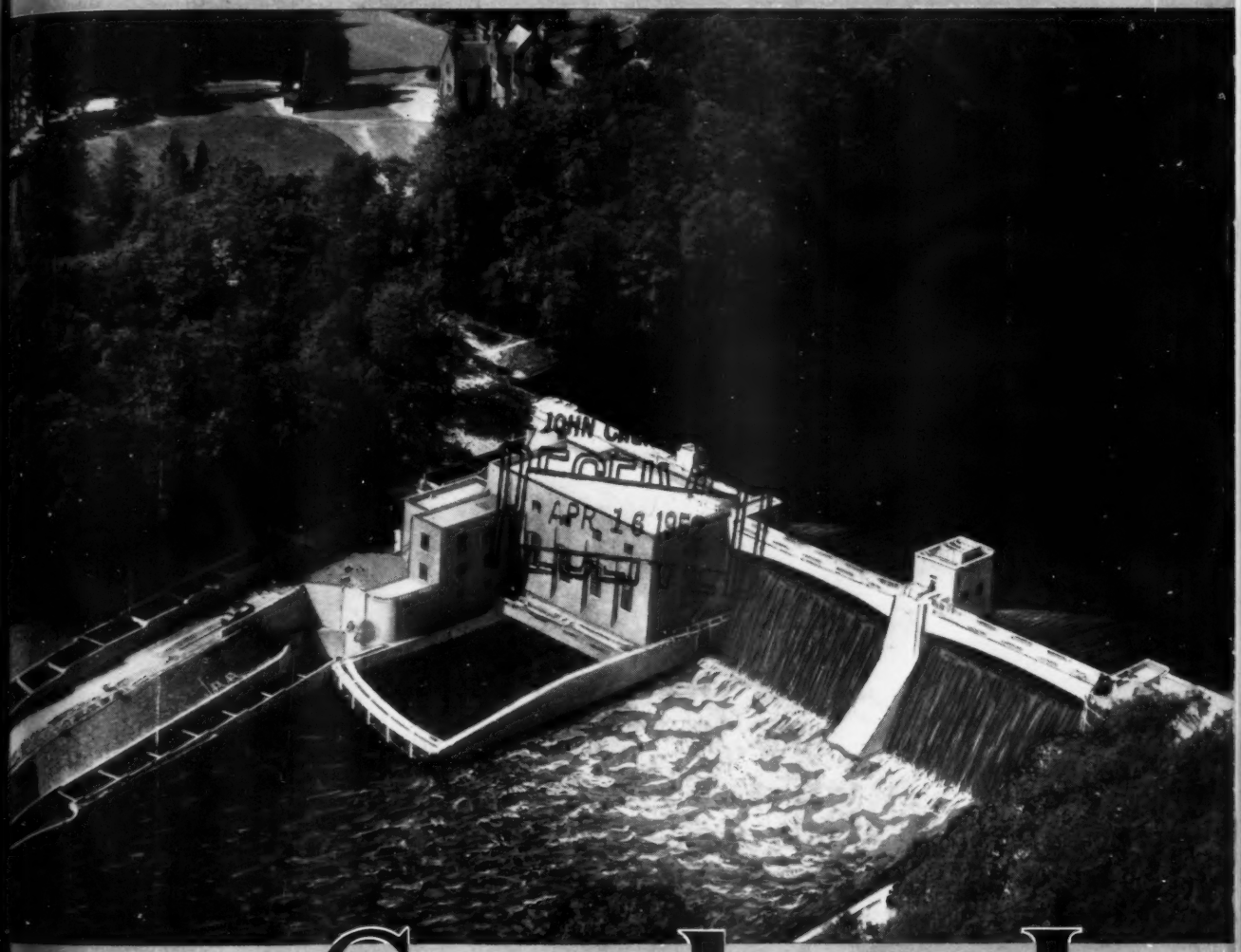
27

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 : APRIL 1952



in Scotland

The Pitlochry station of the North of Scotland hydro-electric Board, shown in the illustration, contains two 8,333 kVA Metrovick vertical Generators driven by Kaplan turbines of Boving manufacture, operating at a normal speed of 167 r.p.m. and designed for an overspeed of 480 r.p.m. Other Metrovick gear in this station is the generator control equipment including the voltage regulators.

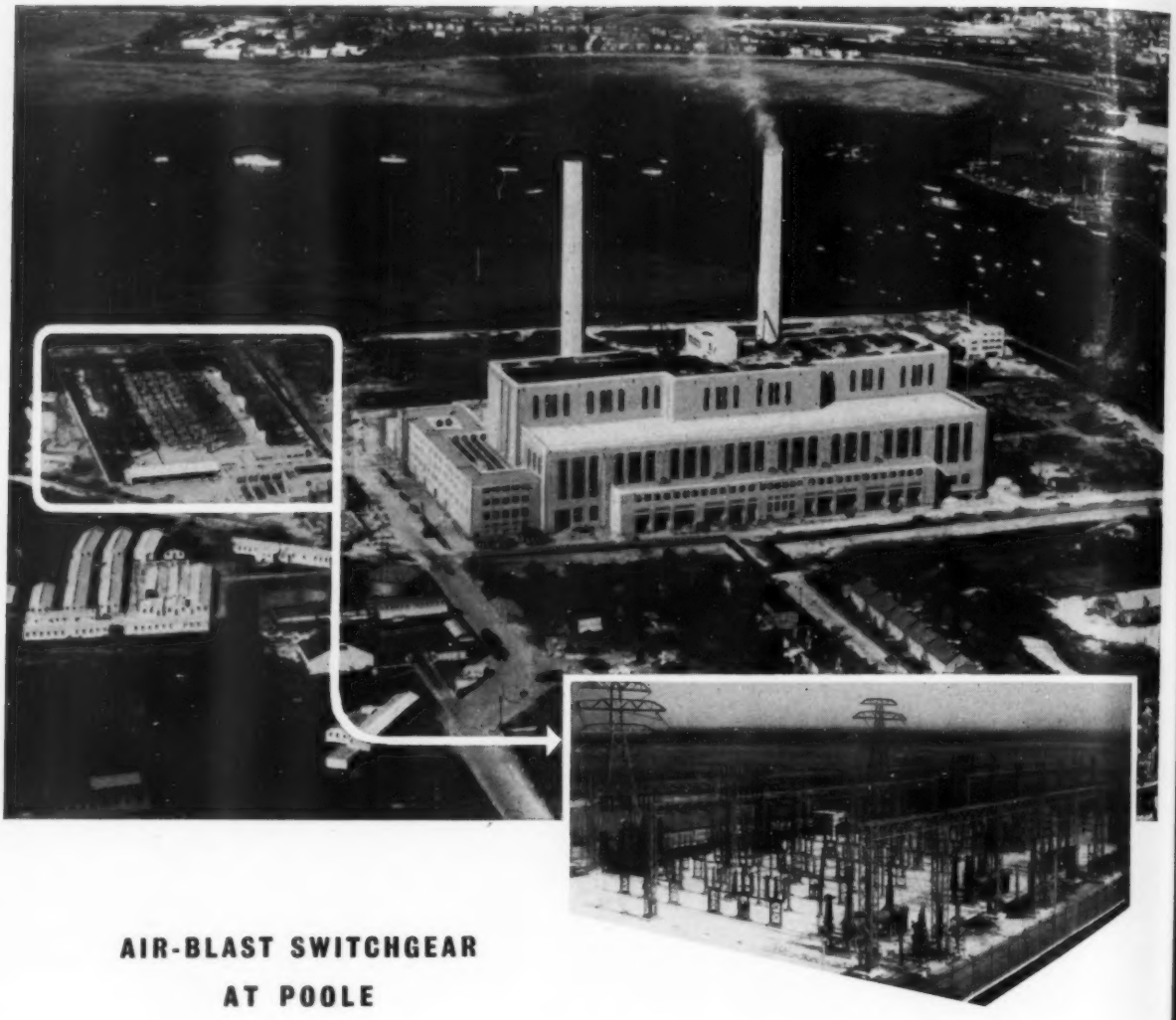
The M.V.E. Co. Ltd. also manufacture Synchronous Condensers, Transformers, Switchgear and automatic control equipment for the largest hydro-electric power schemes all over the world.

Agents in: AUSTRALIA · CANADA, FINLAND · INDIA · PAKISTAN, MEXICO · NORWAY · N. & S. RHODESIA · PORTUGAL · SPAIN, etc.

Offices at: BUENOS AIRES, RIO DE JANEIRO, SHANGHAI · WELLINGTON, etc.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., MANCHESTER 17, ENGLAND

Member of the A.E.I. group of companies



AIR-BLAST SWITCHGEAR AT POOLE

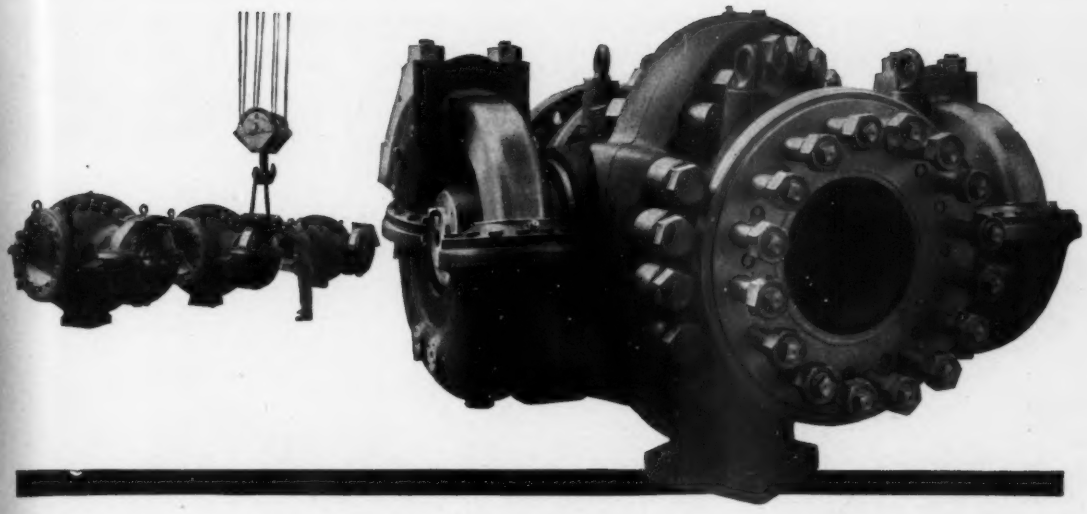
FOR new power stations where the main switching is at 132 kV, Reyrolle air-blast switchgear is particularly suitable. The breaking capacity rating may be 2500 MVA or 3500 MVA and circuit-breakers of the former rating were selected for Poole Power Station.

In addition to the circuit-breakers, the open-type duplicate busbar sub-station has isolators, post-type current-transformers and control equipment all of which were manufactured at Hebburn.

If you want to talk switchgear ... talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

CRC 20 8



Rotary Slide Valve
with hydraulic rotary-piston drive
and dual sealing. Diameter of bore 600 mm.
Working pressure 150 atm.,
Testing pressure 270 atm.,
Face-to-face length 2600 mm.
Height 2100 mm., width 3000 mm.

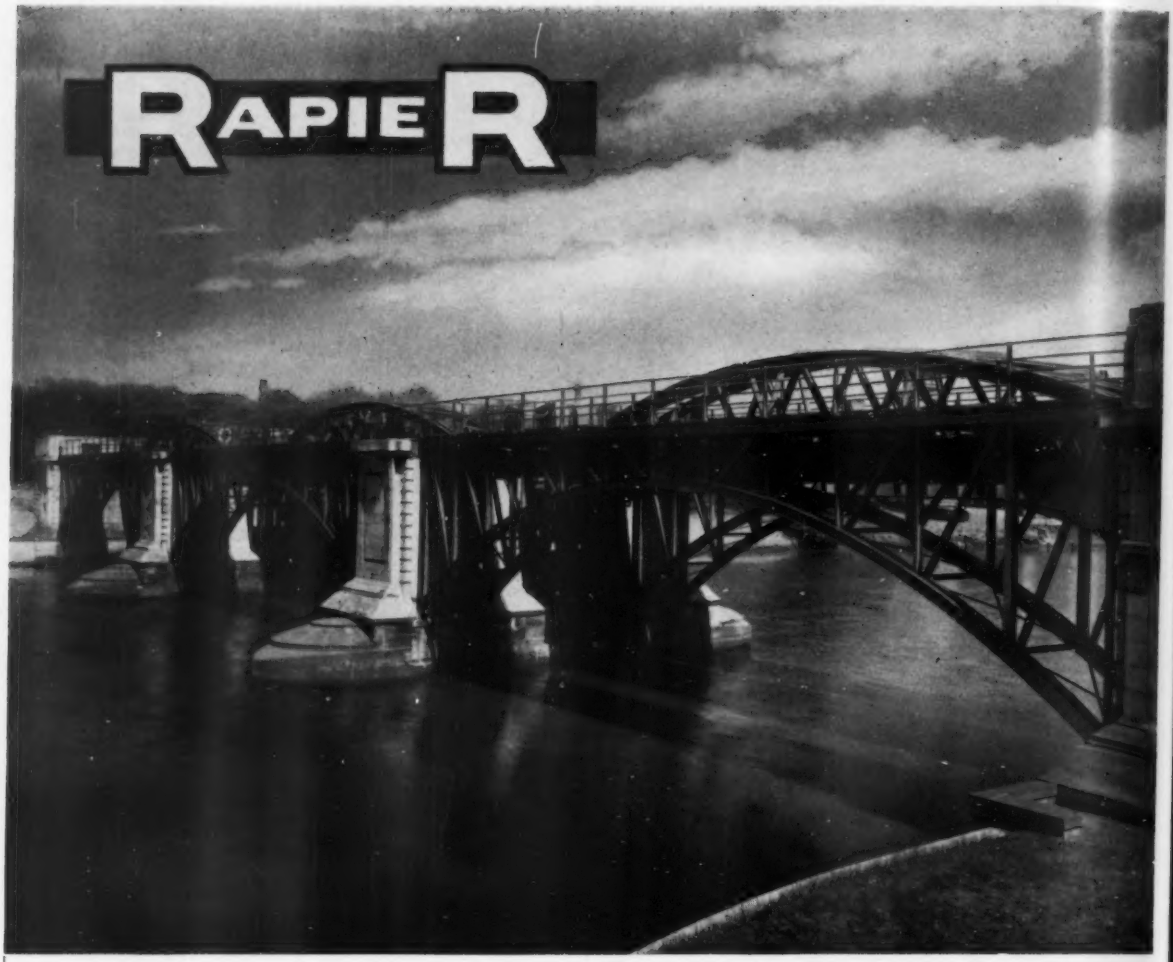
Equipment for Hydro-Electric Power Stations

Complete barrage installations; hoisting equipment and cranes; sluices and sluice-valves; grid clearing machines; shut-off valves for high-pressure conduits; high-pressure conduit fittings; circular slide valves; rotary slide valves with hydraulic rotary-piston drive; shut-off valves for emergency and bottom outlets; piping systems for oil and cooling-water plant; funiculars and aerial cableways for passenger and goods transport; building machinery for dam-building work.

DE ROLL

Louis de Roll Iron Works Ltd., Works at Gerlafingen (Head Office),
Klus, Olten, Rondez, Choindez, Berne (Switzerland)

889



RAPIER

RapieR Gates control flood water and retain the high tide level on the River Clyde in Glasgow. The installation includes three 80-feet span gates, 12-feet deep with bridge work and electric operating gears. The gates automatically turn under the arches in the fully raised positions.

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for

Power Plants **Water Supply**

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Locks & Docks

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IPSWICH—Waterside Works

32 Victoria Street—**LONDON**

Boving
& COMPANY LIMITED

WATER TURBINE ACTUATORS

This is the most modern type of Boving Actuator — the F.10 and it is here seen both in process of assembly, and undergoing test at the works of John Brown & Co. Ltd. at Clydebank.

These Actuators contain the speed-responsive element of the governing system of large water turbines. They are highly sensitive and embody every modern feature to enable them to meet the onerous governing requirements of a large turbine.

In normal practice Actuators are arranged for remote control and the F.10 is particularly suitable for fully automatic plants.

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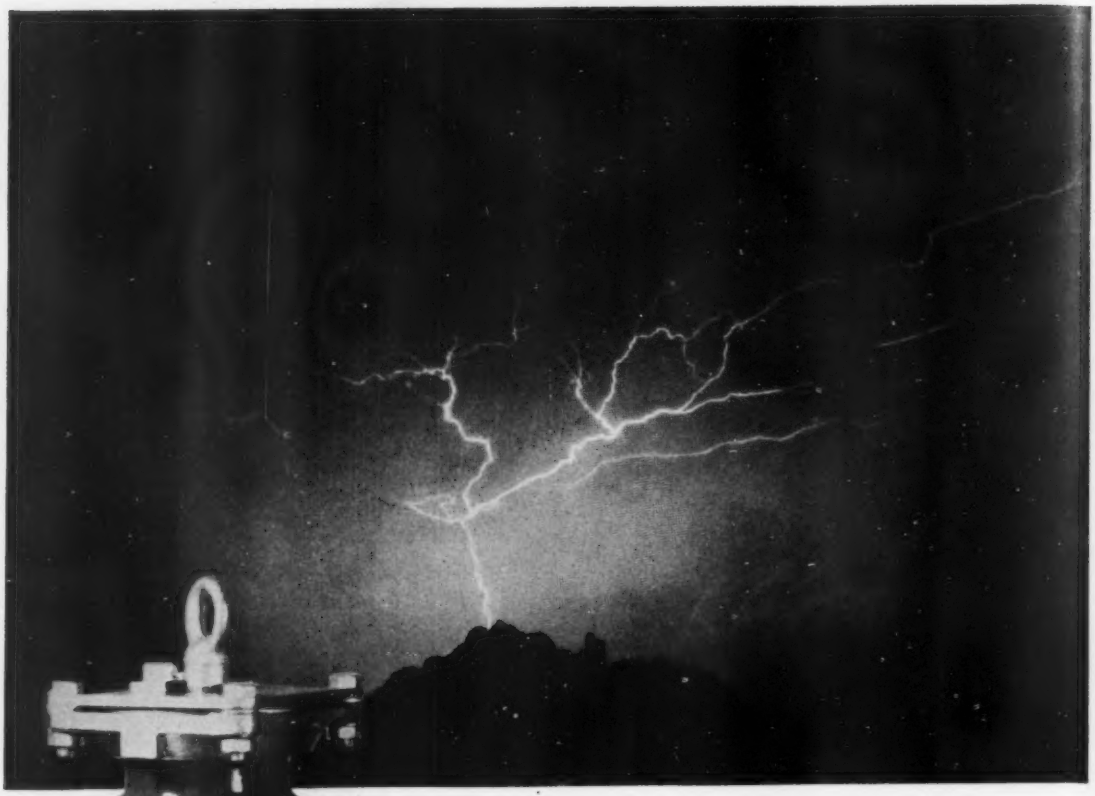
Representatives in all parts of the world.

• WATER TURBINES....PULP & PAPER MACHINERY •



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to be able to grade your system insulation correctly?

to avoid tripping of circuit-breakers and damage to equipment due to over-voltages during thunderstorms?

to utilize your equipment to the full even during periods of frequent lightning storms?

Then select

BROWN BOVERI

LIGHTNING ARRESTORS

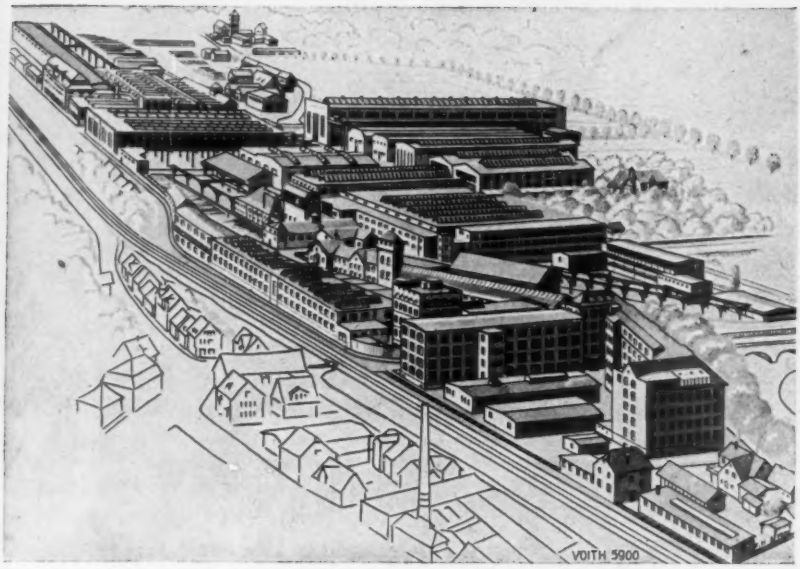
which are designed to meet the special needs of system operation and have proved their worth in service. They will also satisfy your requirements.

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

J.M.Voith G.m. b.H.

A main field of our production program

Manufacture of Voith Water Turbines



Total view of the Voith Engineering Plants

Kaplan Turbines with double regulation, in concrete scrolls or steel plate scroll casings

Francis Open-Flume Turbines with horizontal or vertical shaft

Francis Spiral Turbines with horizontal or vertical shaft, also supplied as double discharge spiral turbines

Impulse Turbines of the single or multi-nozzle type, with horizontal or vertical shaft

Storage Pumps and large-size high-capacity pumps for any delivery head

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Sluice Gates and Weirs
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Penstocks and Shut-off Valves
Gear Drives

J. M. Voith G.m.b.H. Engineering Works
Heidenheim (Brenz), Germany

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DI BATTAGLIA TERME (PADOVA) S. p. A.

Barrage at Bassano del Grappa—4 Sluice gates, 16 metres long, 4.6 metres high, of which two are automatic

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BRIDGES
TANKS
TRUSSES
HOPPERS
LIFTS
AND ALL TYPES OF STRUCTURAL STEELWORK & GENERAL ENGINEERING

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- 6 large establishments in Italy.
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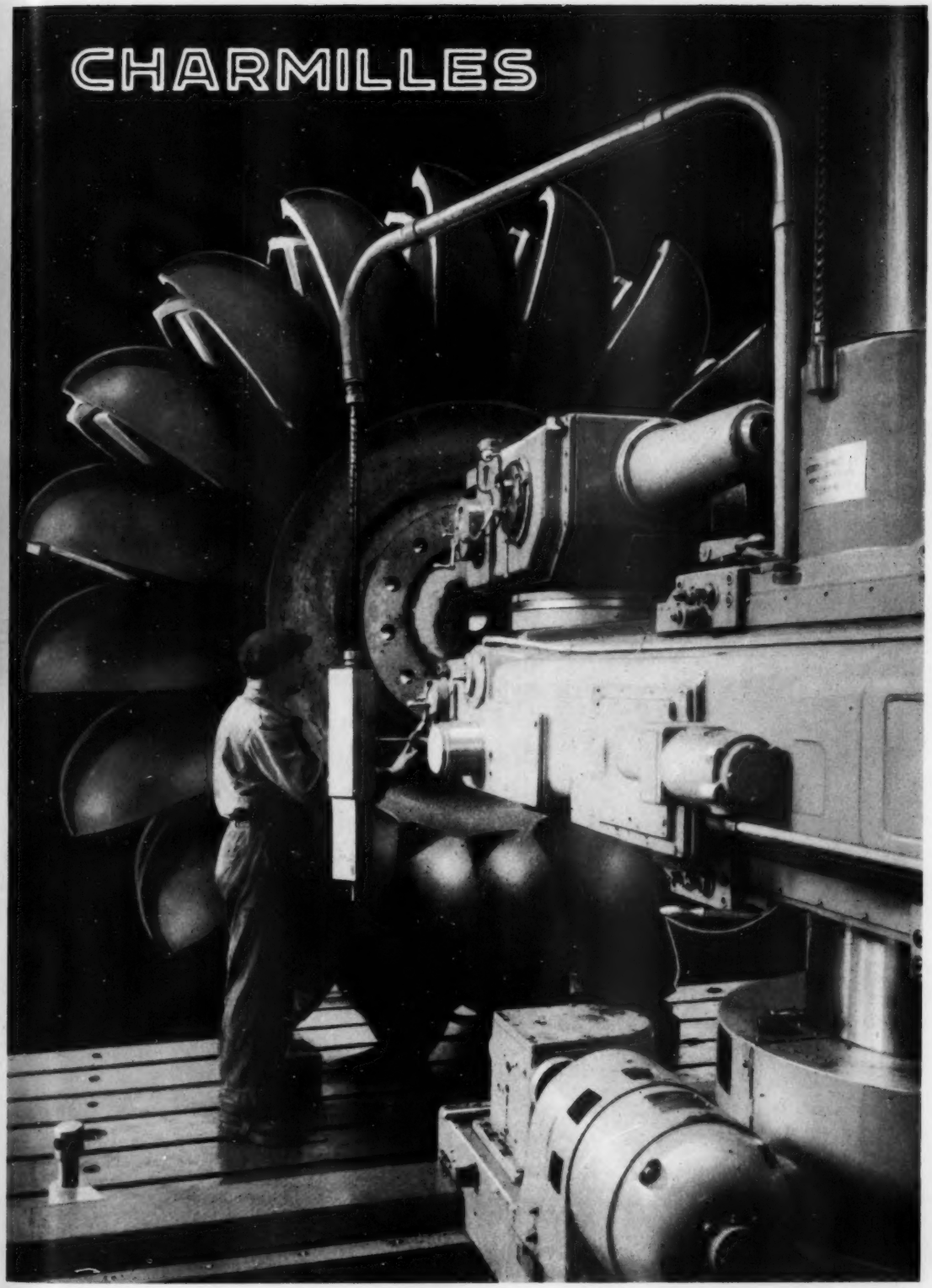
- important contracts carried out for key industries in Italy and throughout the world.

GALILEO WORKSHOPS OF BATTAGLIA TERME S.p.A. PADUA, ITALY. PHONE: PADUA 25689-26003 GRAMS: WORKSHOPS. BATTAGLIA. TERME. ITALY



HYDRAULIC TURBINES

—CHARMILLES ENGINEERING WORKS LTD., GENEVA—

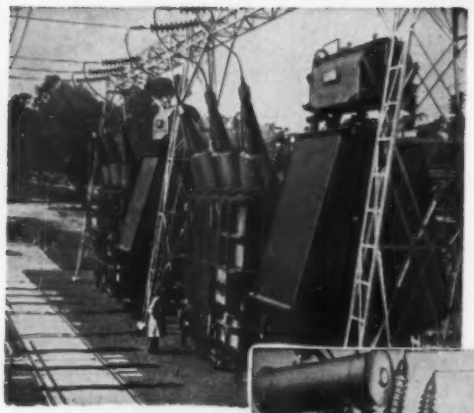
HACKBRIDGE TRANSFORMERS

for

HIGH VOLTAGES

and in the

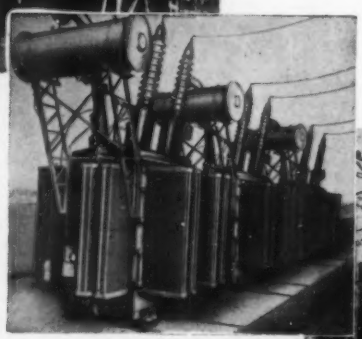
LARGEST CAPACITIES



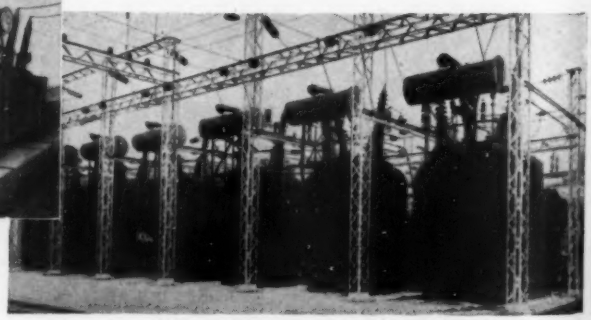
An installation of large Hackbridge transformers in Australia.

HACKBRIDGE Transformers include some of the world's largest units — in capacities up to 94,000 kVA. three-phase—many of these being in service in hydro-electric power stations.

Through over a quarter of a century, these — and all other types of Hackbridge transformers —have achieved a magnificent reputation for reliability and sound modern design and construction.



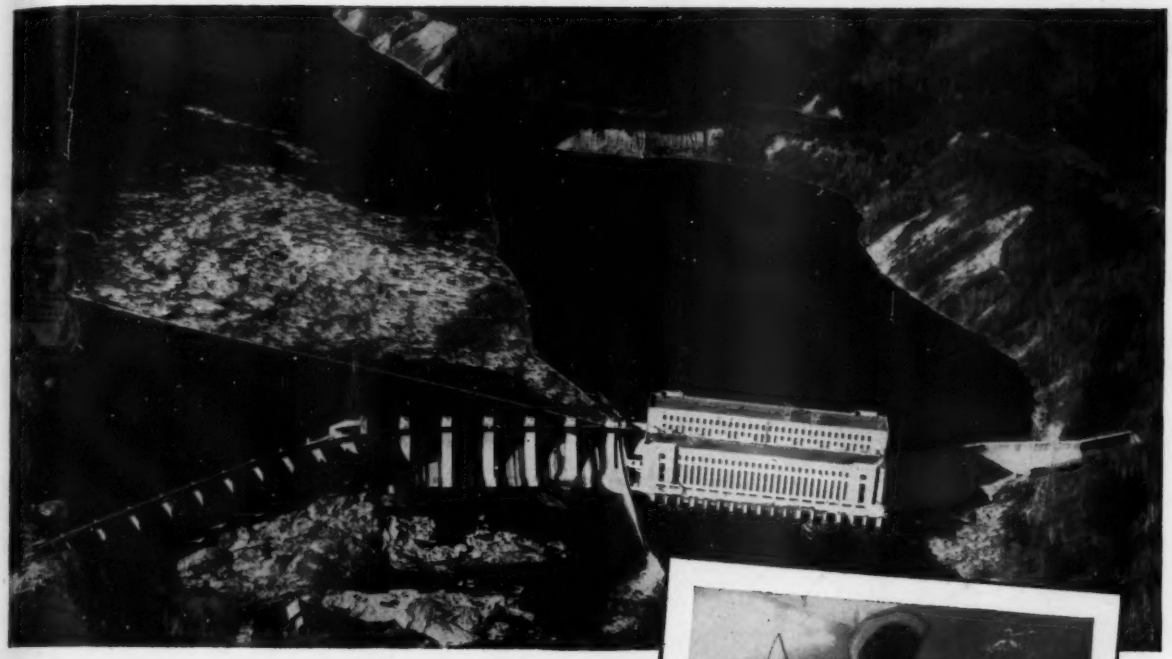
Three 6,666 kVA single-phase Hackbridge transformers forming 20,000 kVA 110/38.5/6.6 kV. 3-phase bank.



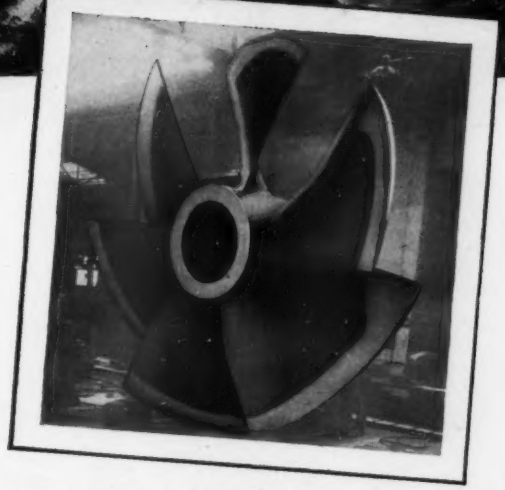
Two 18,500 kVA. 3-phase 102/11/6.6 kV. banks of Hackbridge transformers installed in Tasmania.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD., WALTON-ON-THAMES, SURREY

Telephone: Walton-on-Thames 760 (8 lines) Telegrams: "Electric," Walton-on-Thames



The La Gabelle plant of the Shawinigan Water and Power Company, containing five Dominion fixed blade propeller turbines of 35,000 H.P. each, at 120 R.P.M. under a head of 60 feet.



Economy with DOMINION PROPELLER TURBINES

For low head hydro-electric power plants, where high speed is essential for economy in capital cost, the fixed blade propeller turbine is often the most suitable particularly when there are multiple units in the power house.

The fixed blade propeller turbine is as simple in construction and operation as the lower speed Francis turbine. It does not require the complicated mechanism and governor control, in the rotating element, of the adjustable blade propeller turbine. Nevertheless, the fixed blade propeller turbine, in many installations, utilizes the available hydraulic power as effectively as the more expensive type.

Since 1921 Dominion Engineering have received orders for 89 fixed blade propeller turbines with a total rated capacity of 1,244,245 H.P., and are now manufacturing 14 units of this type, with throat diameter of 205″. Eight units, of 21,000 H.P. each, at 94.7 R.P.M. under a head of 40 ft. are for the Chenaux Development of Hydro-Electric Power Commission of Ontario, and six units of 19,000 H.P. each, at 94.7 R.P.M. under a head of 37 ft. are for the Pine Falls Development of Department of Mines & Natural Resources, Province of Manitoba.

This background of experience, combined with a systematic research programme in our own laboratory, is at your service. We confidently invite your enquiries.

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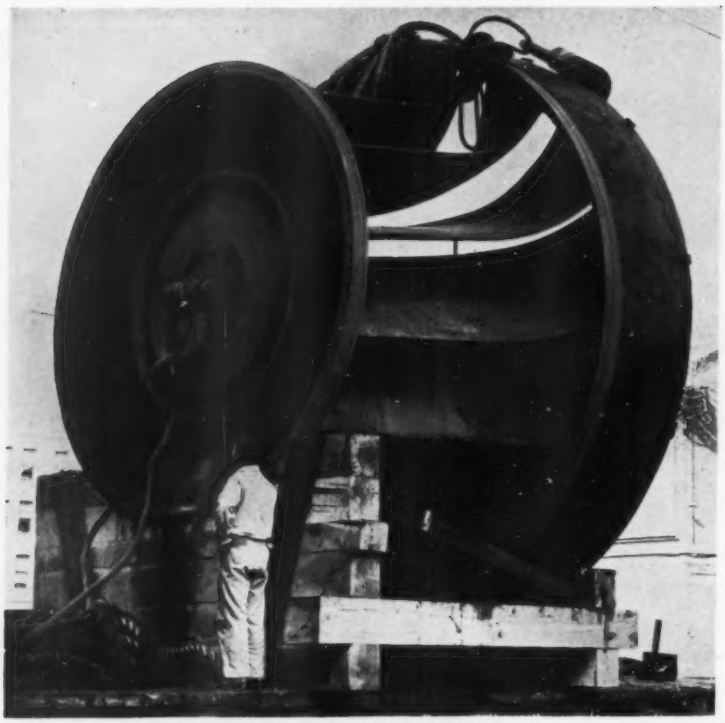
DOMINION ENGINEERING
COMPANY LIMITED
MONTREAL, CANADA **D** **CABLE: DOMWORKS**



RUNNER FOR BUGGS ISLAND DEVELOPMENT

OVER EIGHT MILLION HORSEPOWER

The Newport News Shipbuilding and Dry Dock Company has received orders for the building of hydraulic turbines aggregate rated output of 8,135,000 horsepower.

ASSEMBLY OF SPIRAL CASINGS FOR C. J. STRIKE DEVELOPMENT

NEWPORT NEWS
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Impulse runner of *solid-cast* design, an exclusive SMITH advantage.

FOR HIGH HEADS, and wherever the head and water quantities available prohibit the use of reaction-type machines. Ideal for installations in remote localities because of the ease with which the completed unit may be transported. The simplicity of design, facility of operation and greater dependability remove the necessity of skilled operators and attendants. Smith's solid-cast runner design provides the additional advantages of closer spacing of buckets resulting in increased speed and consequently, a decrease in the size of the turbine unit, as well as the generator. Write for your copy of our Bulletin — "Impulse Turbines by SMITH!"

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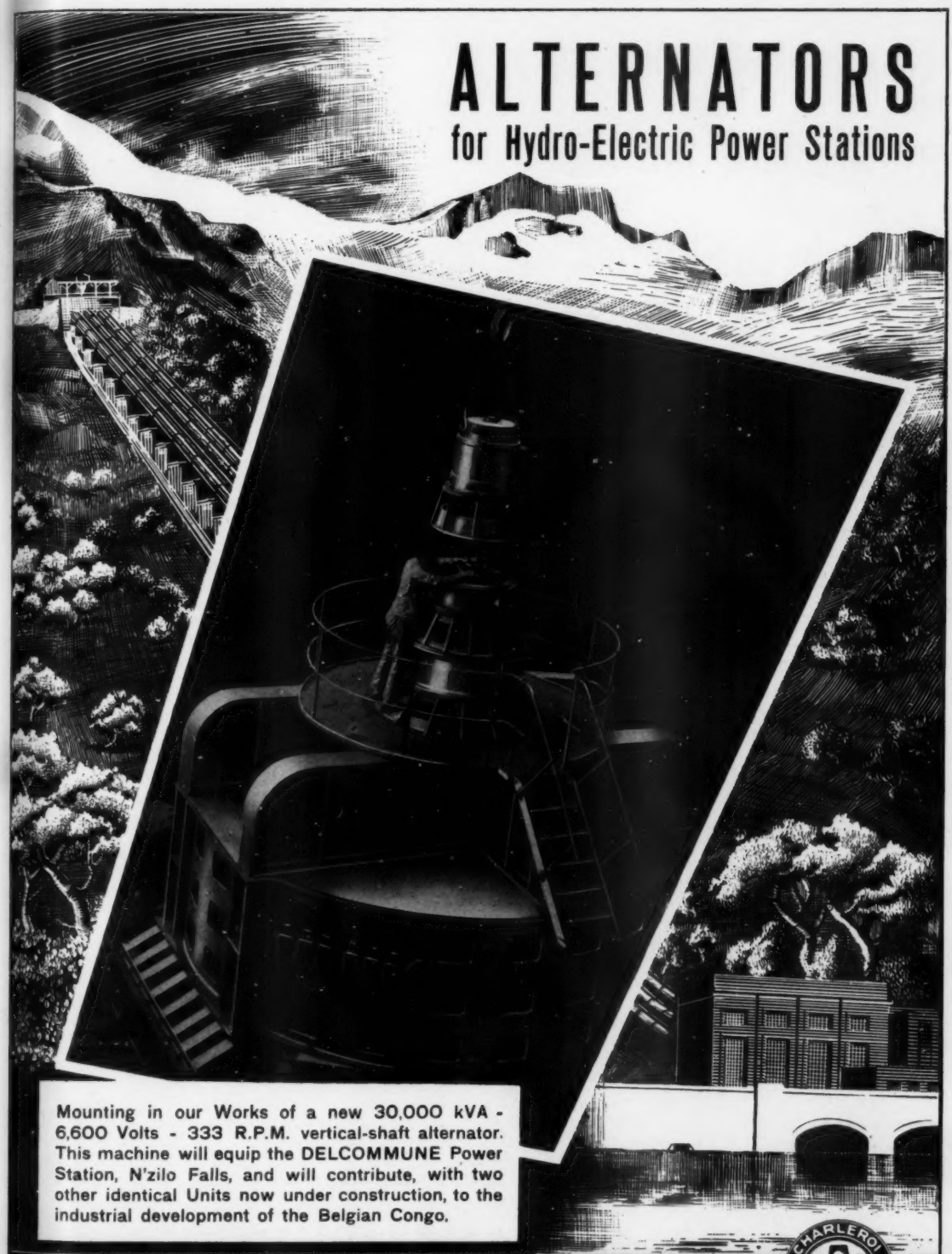
POWER by SMITH

ALTERNATORS
for Hydro-Electric Power Stations



Mounting in our Works of a new 30,000 kVA - 6,600 Volts - 333 R.P.M. vertical-shaft alternator. This machine will equip the DELCOMMUNE Power Station, N'zilo Falls, and will contribute, with two other identical Units now under construction, to the industrial development of the Belgian Congo.

ATELIERS DE CONSTRUCTIONS ÉLECTRIQUES DE CHARLEROI

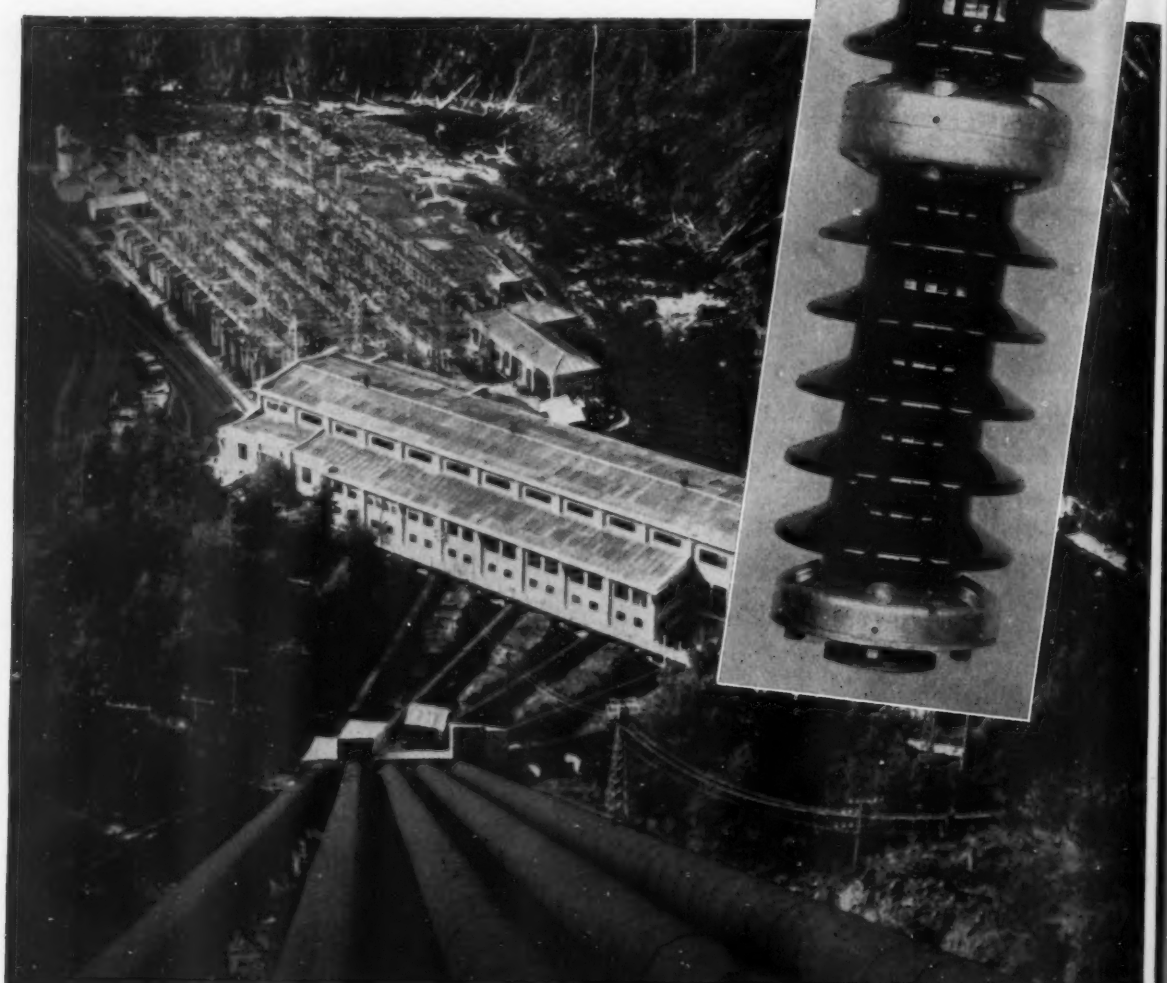
CHARLEROI CAC

S.P.P. Post Insulators

were specified for the

Tarraleah Sub-Station, Tasmania

All S. & P. Cylindrical Post Insulators are protected by British Letters Patent



The Sub-station at Tarraleah, Tasmania, is one of the many 110 kV. and 88 kV. sub-stations on the Hydro-Electric Commission's system equipped throughout with S.P.P. Cylindrical Post Insulators.

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Leffel turbines give you maximum power from your available water, and with a very minimum of attention. For year-in year-out turbine service specify Leffel—backed by 90 years of progressive engineering and dependable construction. Let Leffel's expert hydraulic engineers solve your water power problems (whether they're special or ordinary). Inquire now, without obligation.

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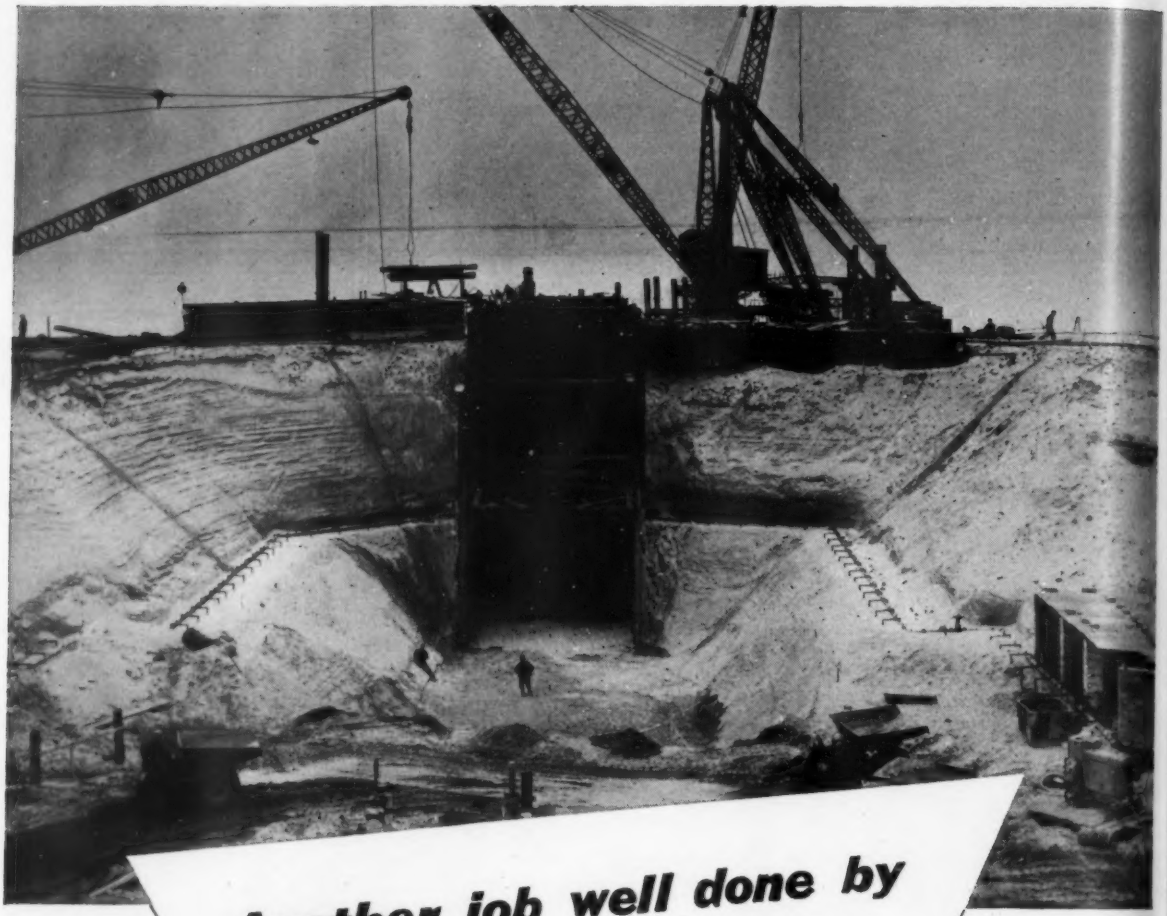
THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 90 YEARS



Another job well done by Millars' Wellpoints

Discharge Culvert connecting the Main Flume with the Cofferdam going out to sea at the Carmarthen Bay Power Station. In this contract the water table has been successfully lowered from ground water level at 108 ft. to a depth of 74 ft.—sub grade being 76 ft.—by the use of Millars' Wellpoint Dewatering System. The top of the bank is 2 ft. above high tide. This is an excellent example of the efficiency of this equipment under difficult conditions and it can be seen from the photograph that the excavation is completely dry.

Write for further details to Dept. W.P.4

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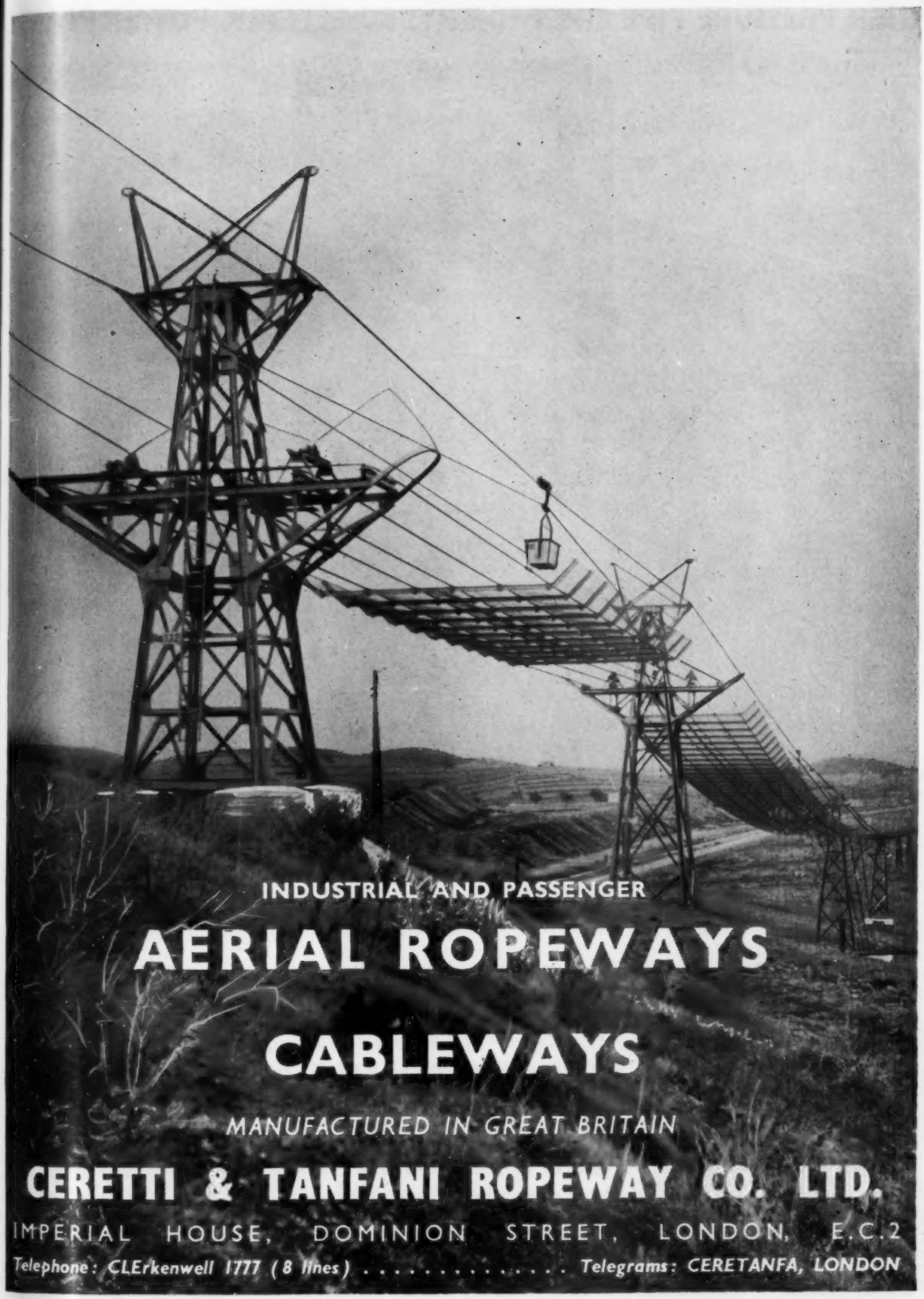
33-454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HIGH PRESSURE PIPE LINES FOR HYDRO-ELECTRIC POWER PLANTS

FERRUM (England) LIMITED, London, and their Associate Company, FERRUM MONTAGE A.S., Oslo, Norway, have for many years specialized in Design, Supply and Erection of High Pressure Pipe Lines for Hydro Electric Power Plants.

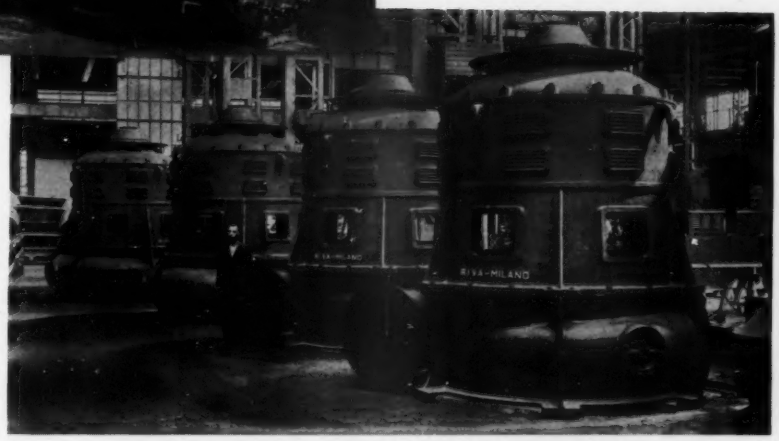
More than 300 contracts have been carried out by the Ferrum Organization for supply of High Pressure Pipe Lines to all parts of the world. Since the beginning of 1946 Contracts for the Supply and Erection of High Pressure Pipe Lines have been placed with our Organization for 43 separate Hydro-Electric Installations, including highly important Power Plants in Norway, India, Tasmania and Australia.

We shall be pleased to send on application the Ferrum pamphlet and supplementary list

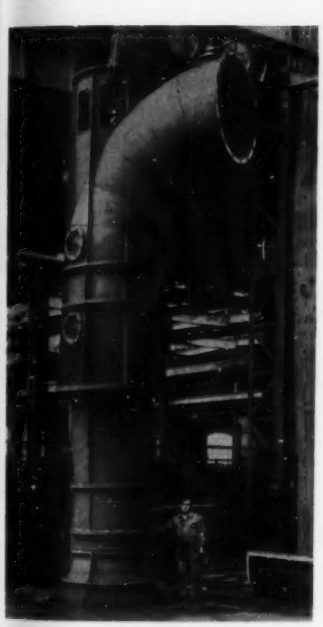
FERRUM (England) Limited ENGINEERS

STAFFORD HOUSE, 43 NORFOLK STREET, LONDON, W.C.2

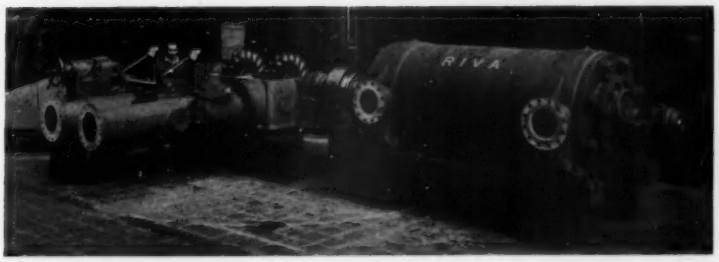
40,000 H.P. multi-stage centrifugal Storage Pump manufactured by RIVA and installed at the PONALE POWER STATION, Italy. This Pump is designed to work against a head of 2,000 feet with a maximum delivery of 900 gallons per second and is the only one of its size and type in the world built for these working conditions. Ferrum (England) Ltd. will be pleased to supply on application a leaflet describing and more fully illustrating this pump.



Vertical Shaft Centrifugal Pump, designed for varying heads of between 15 m and 40 m. Discharge 1500 to 3400 l/s. Speed 415 r.p.m.



Vertical Shaft Propeller Pump. Head 1 m, 28/5 m, 66—discharge 3350/2550 l/s—Speed 485 r.p.m.



Horizontal Shaft Multi-Stage Centrifugal Pump, operates against a head of 375 m. Discharge 200 l/s. Speed 1000 r.p.m. This pump is driven by a Riva double impulse turbine of 1250 H.P.

The total output of Pelton, Francis and Kaplan Turbines designed and manufactured by RIVA exceeds 8,000,000 H.P.

COSTRUZIONI MECCANICHE RIVA
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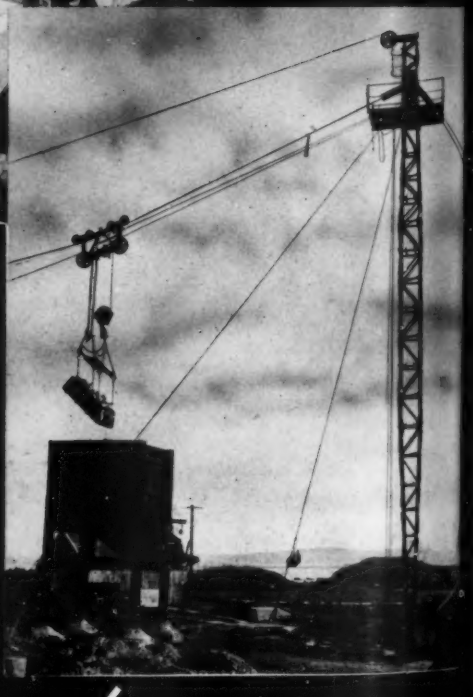
Sole Representatives for UNITED KINGDOM, CANADA, SOUTH AFRICA, SOUTHERN RHODESIA, TASMANIA, CEYLON, PAKISTAN, AND ALL BRITISH COLONIES AND THE REPUBLIC OF EIRE

FERRUM (ENGLAND) LIMITED, Engineers, 43 NORFOLK STREET, LONDON, W.C.2

Giant hydro-electric schemes in all parts of the world make use of BRECO Aerial Cableways and Ropeways for the transportation of vital materials.

The largest builders of heavy capacity Cableways and Ropeways in the world, BRECO will supply advice and technical information willingly, and without obligation.



BRECO *Aerial* ROPEWAYS

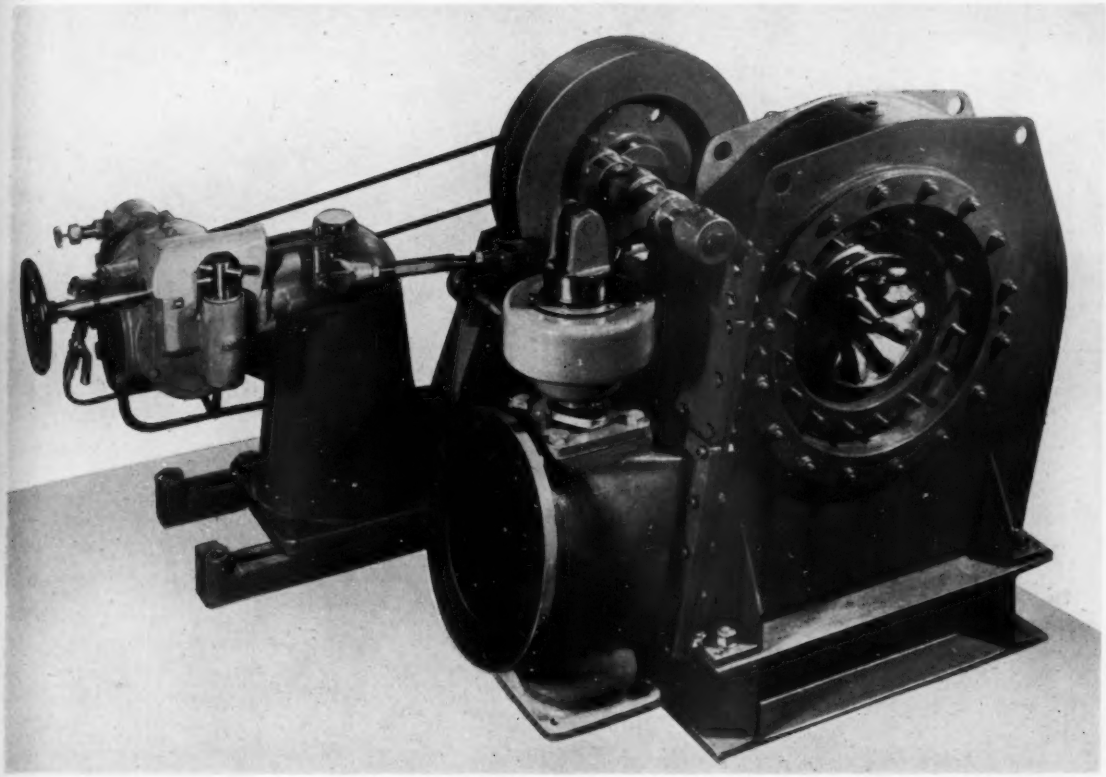
BRITISH ROPEWAY ENGINEERING CO LTD PLANTATION HOUSE MINCING LANE LONDON E.C

Specialists

IN THE DESIGN AND MANUFACTURE OF

WATER TURBINES

UP TO 1,000 B.H.P.



OIL-PRESSURE GOVERNORS

SLUICE GATES

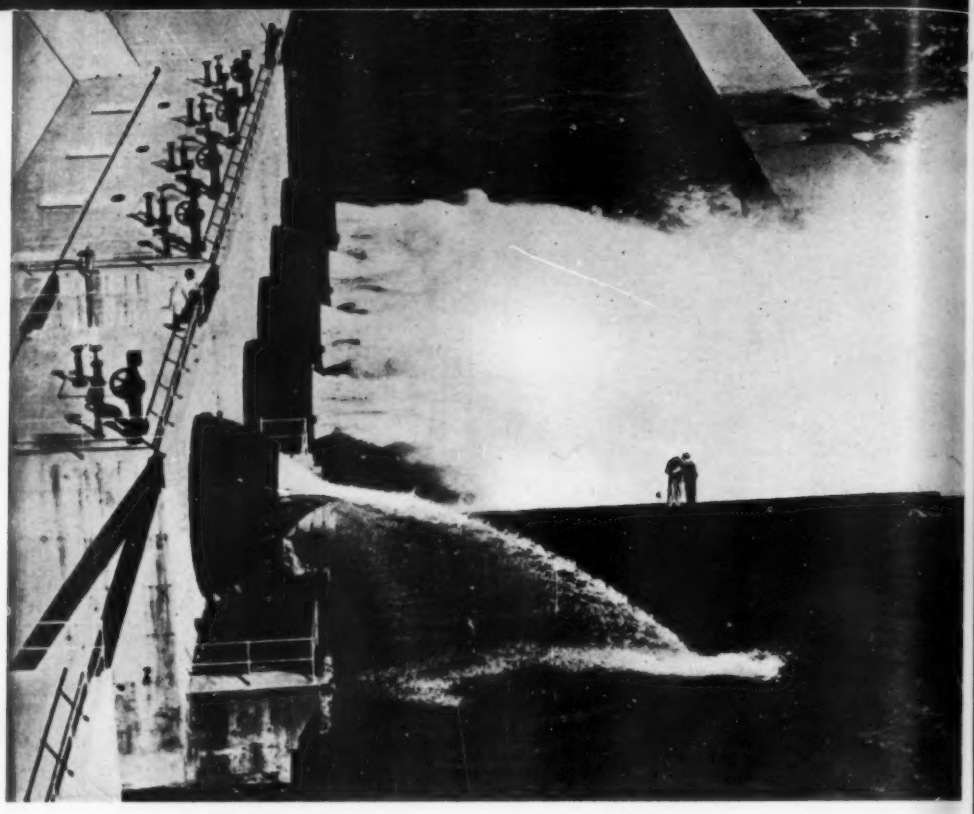
AND COMPLETE HYDRO-ELECTRIC INSTALLATIONS

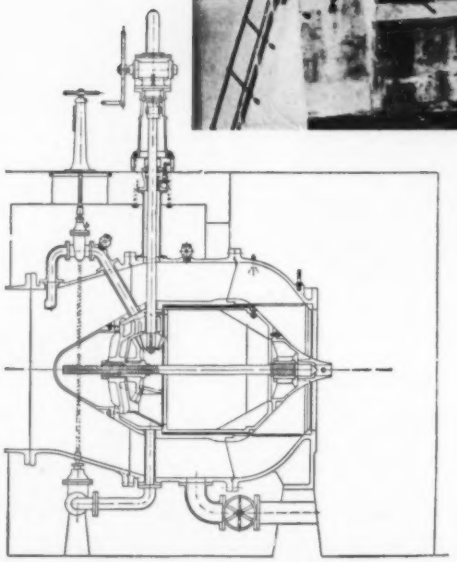
Equipment for a small Hydro-Electric installation in Peru. The fabricated steel volute case houses a 9″ nominal diameter Francis runner. It will be observed that a small automatic oil pressure governor and relief valve are also included in the illustration. This turbine is designed to give 25 B.H.P. under a net head of 67 ft.

THE Armfield HYDRAULIC ENGINEERING CO. LTD.

RINGWOOD · HAMPSHIRE · ENGLAND

DISCHARGE REGULATORS FOR DAM OUTLETS





The Larner-Johnson valve possesses exceptional qualities for free discharge control. No other valve provides so complete an answer to the dual problems of high velocity flow and hydraulic unbalance associated with this duty. Being of true streamline form, it passes a smooth jet at all openings, giving freedom from vibration and erosion under the highest heads. Operation is by means of the pipe line pressure acting on the plunger, governed by an internal pilot valve control which holds the plunger in balance at all open positions (when stationary) and creates the appropriate unbalance for opening or closing. Ease of operation is thus ensured, irrespective of size or pressure. Simplicity of design, freedom from distortion troubles, absence of sliding surfaces under pressure, all contribute to the success of the valve over the full range of conditions. Some of the largest valves of their class are of Larner-Johnson type, amongst them the three 13 ft. by 7 ft. 6 in. and four 9 ft. by 7 ft. 6 in. regulators at Hume Dam, on the Murray River, Australia, certain of which appear in the adjoining photographic view.

Full particulars from : J. Blakeborough & Sons Ltd., Brighouse, England.

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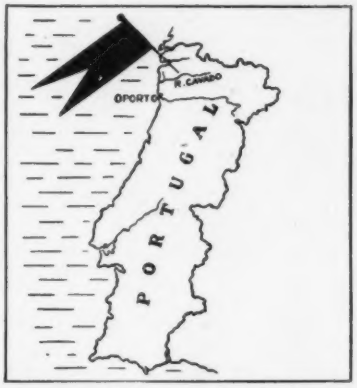
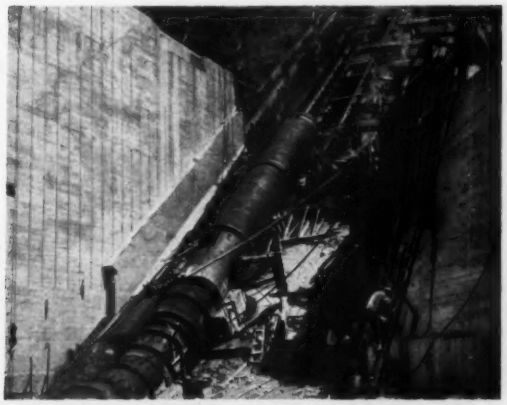


The South Durham steel pipe is in diameters 93″, 87″, 79″, 32″ and is electrically welded throughout with spigot and socket jointing for welding in situ. The pipe thickness is $^{13}/_{16}$″ to 2$\frac{1}{8}$″ for a working pressure at Power House of 590 lbs. per square inch. Total weight of the pipe line is 2,000 tons and all pipe and special pieces were erected, welded and tested by South Durham engineers and skilled workmen.



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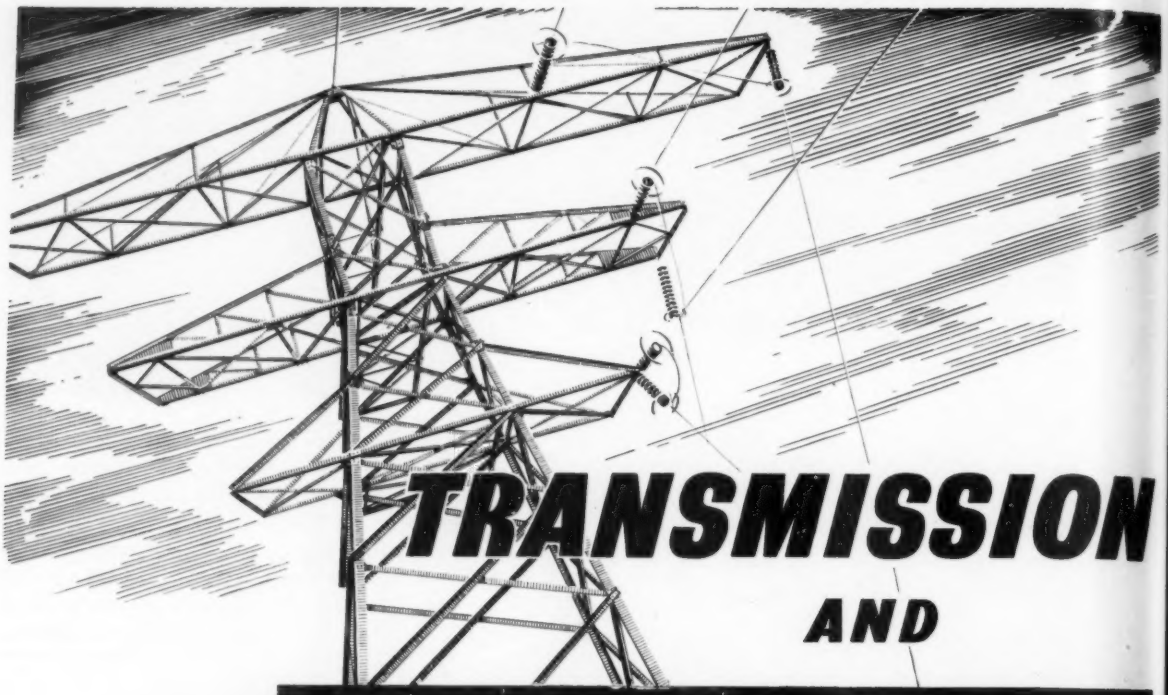

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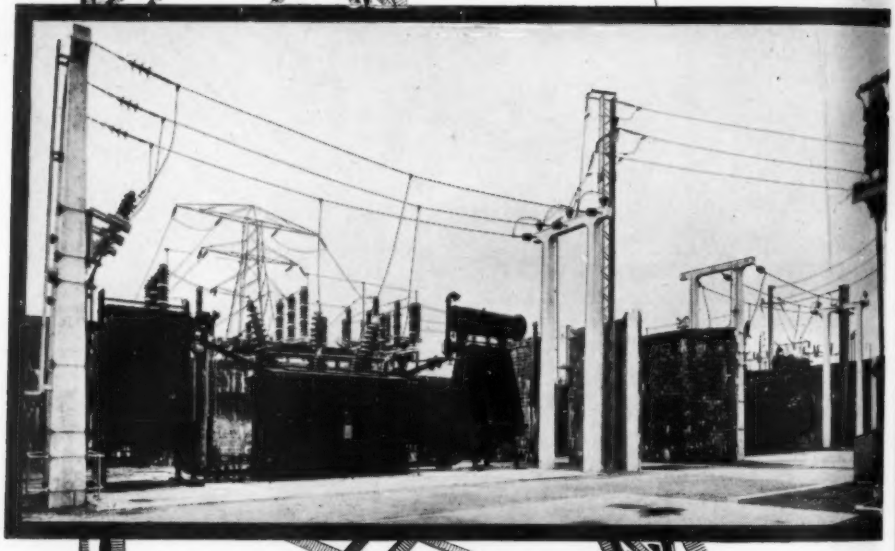

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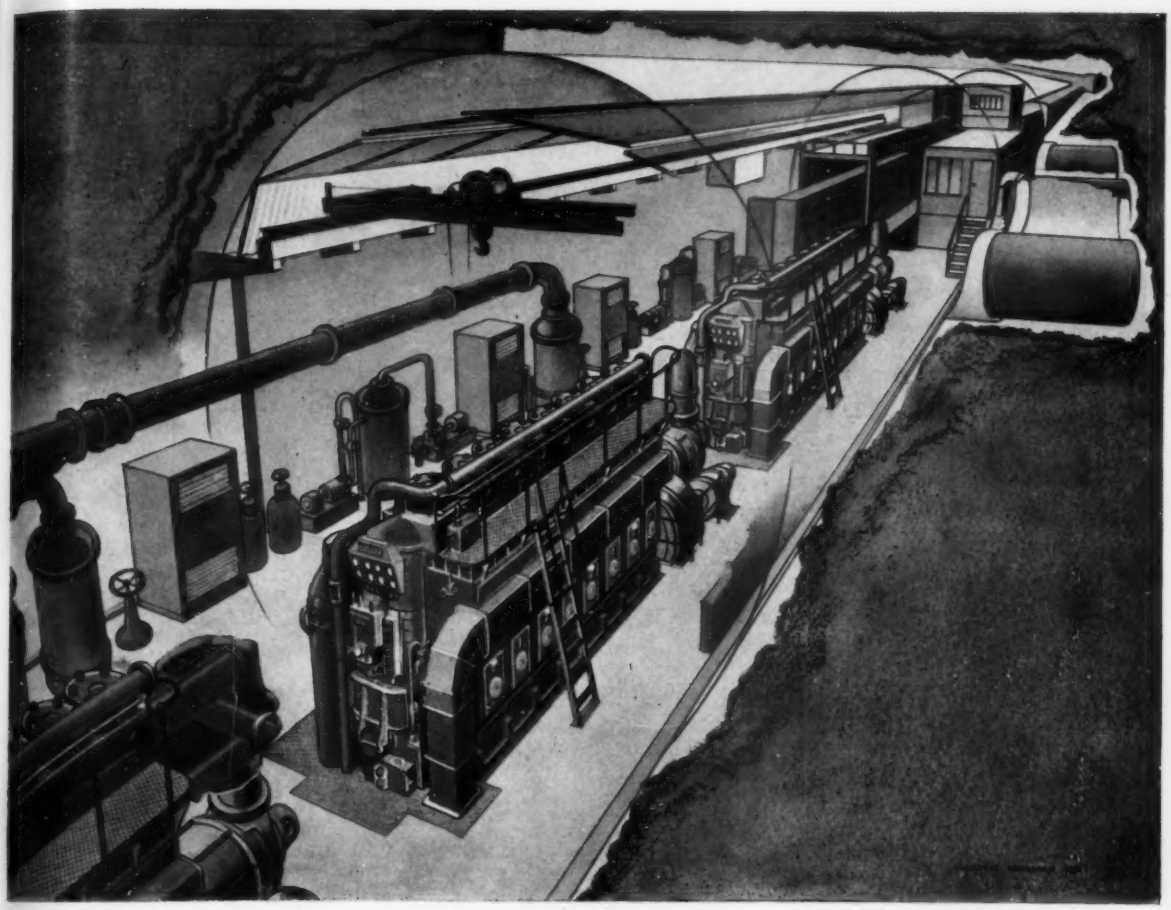

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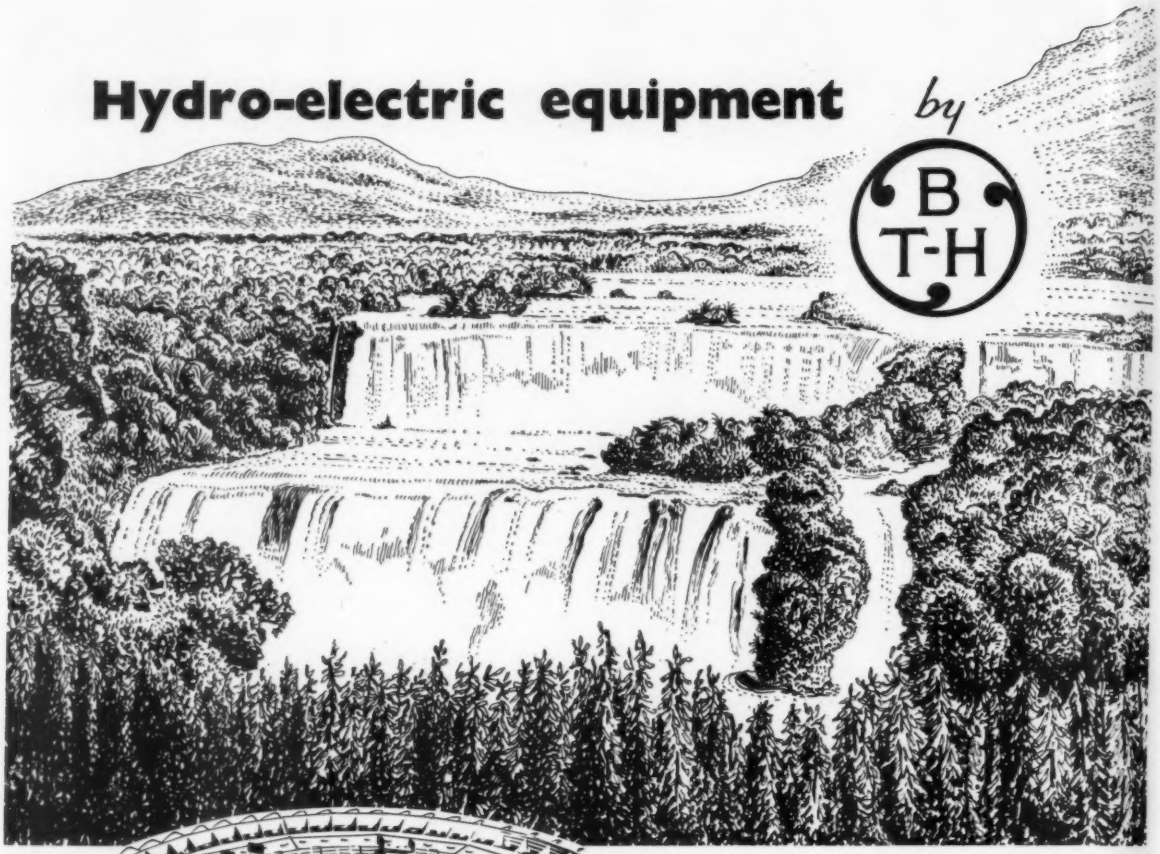

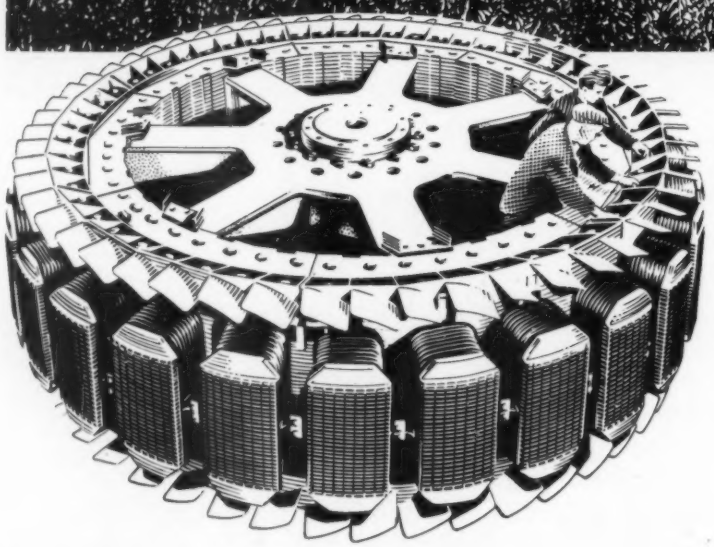

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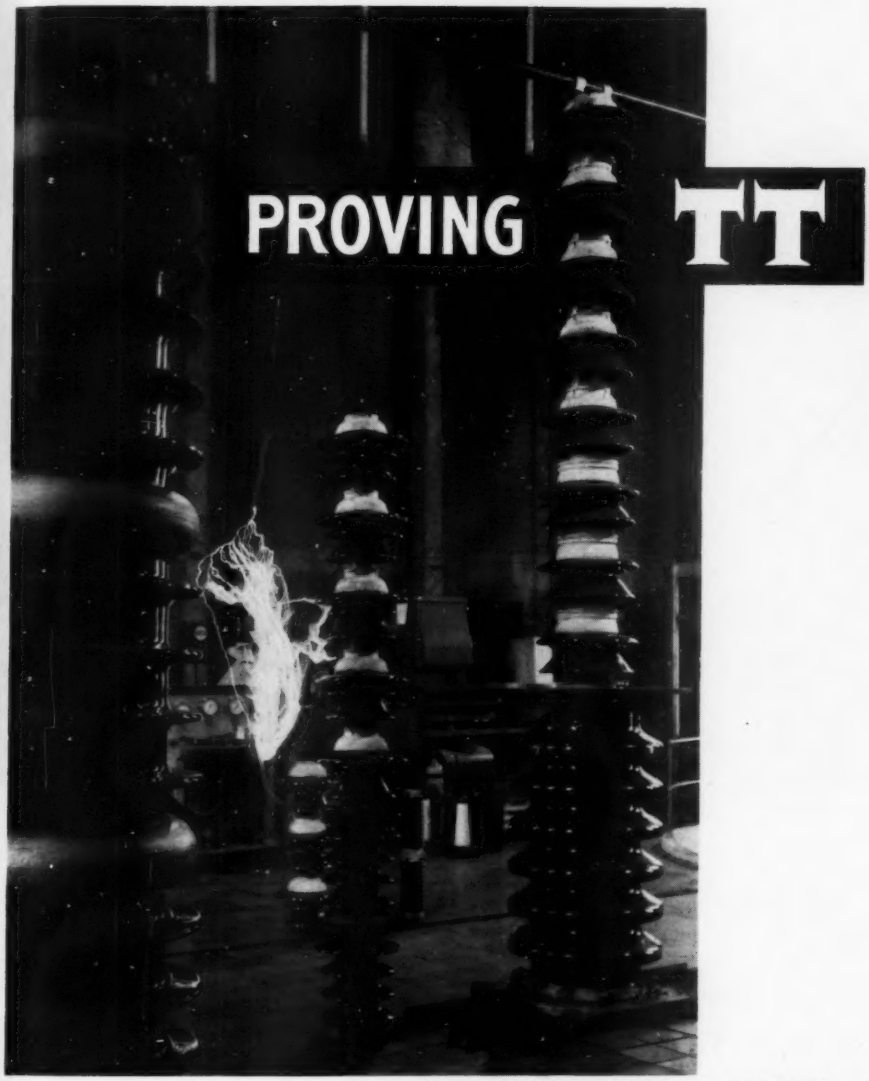

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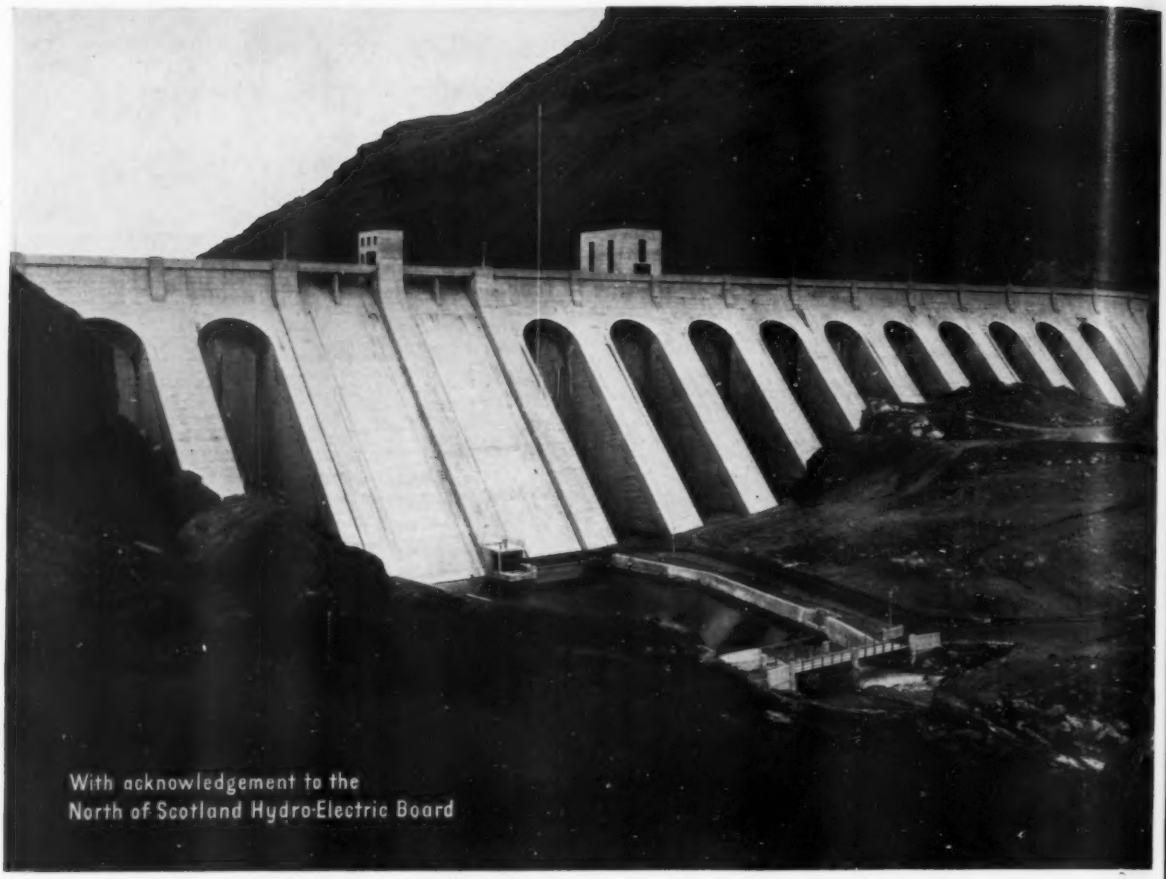

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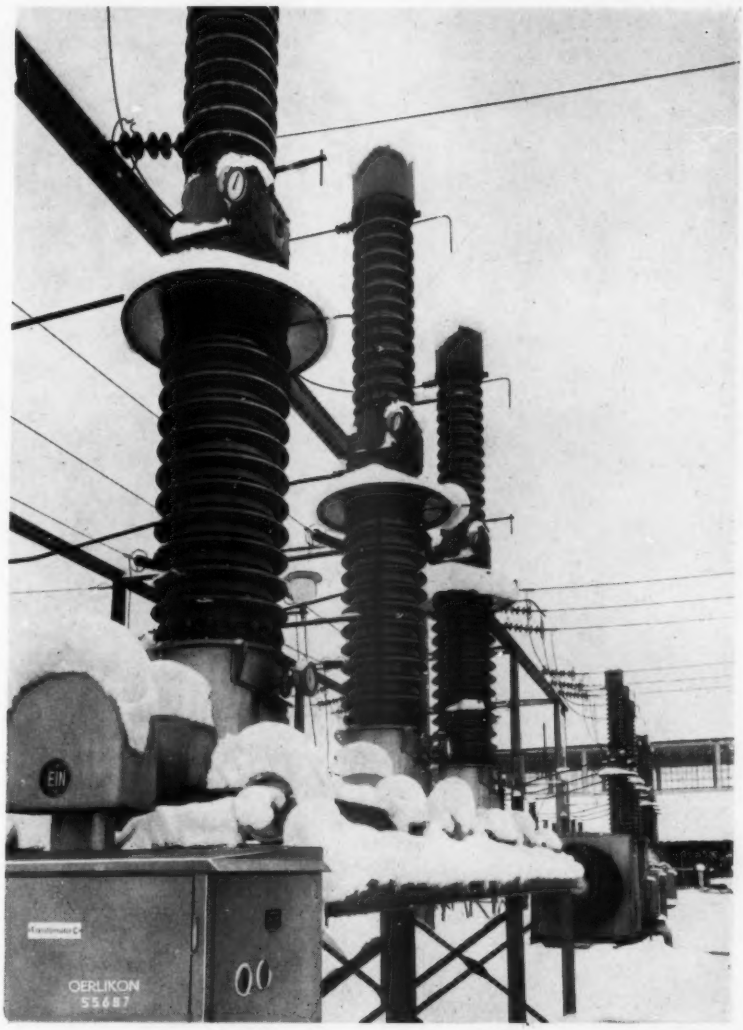

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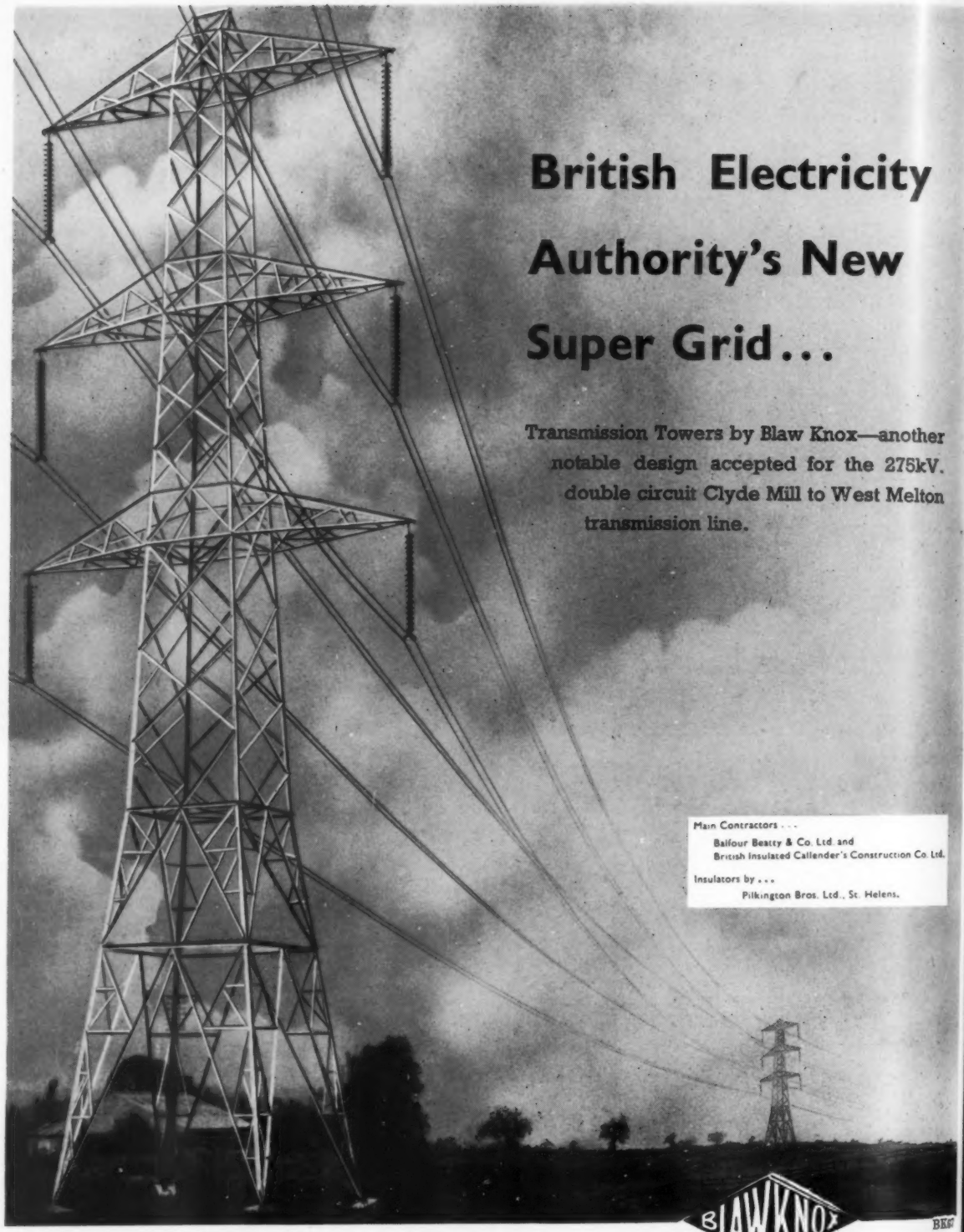
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Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl. London. Telephone: Whitehall 9233 (12 lines).
MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466.
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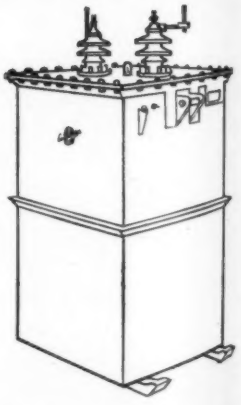

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Higher and Higher?

AT this time of year we begin to receive preliminary statistics showing the trend of power consumption of various electricity authorities and national electricity administrations from all over the world. The 1951 figures are, as yet, incomplete in many ways, but such figures as have been received show only too clearly that there is no visible sign of slackening in the demand, which continues to rise in the form of an exponential curve. The American figures show this tendency very clearly; the Swiss figures reveal a rate of rise of demand scarcely less steep. In France, in spite of economic difficulties of every kind, the curve continues to shoot upwards.

Every day, some 55,000 extra mouths—after taking account of corresponding daily mortality—arrive on earth, and at once require not only food but, in these times, their share of electrical energy. In spite of major wars, famines, earthquakes, and all other disasters, the past ten years saw about 200,000,000 more people existing on the face of the earth. Many of these, it is true, will not use or even see the use of electric power; but equally very many of them will be engaged in industrial work which implies the help of electricity. In America, the 1949 demand for power was 94 per cent. greater than that which existed in 1940.

The principal factors which tend towards an even greater accentuation of the steepness of the curve of electrical energy demand are the feverish race for rearmament taking place, at any rate, among most of the Western industrialised nations; the continual search for higher productivity, which usually ends up by suggesting that more electrical power should be supplied to the "elbow" of each worker; and, perhaps even more potent than any of the others in the long run, the inexorable pressure towards higher standards of living engendered by the slow but certain rise in the educational levels of the mass of the people everywhere.

Against the continuance of the rate of rise of steepness of the curve is the fact that if it were taken to its logical conclusion we should soon reach a stage where no conceivable action on the part of mankind could provide increased supplies of generating plant at a rate sufficiently rapid to meet the demand, and thus there would be the spectacle of a permanently power-starved world.

Thus, one has to consider the natural laws of growth. Nothing that exists in nature, and no activity of mankind has ever been known to continue to grow without some factor, some time, reversing the process. Trees, and all kinds of natural growths, may shoot up with amazing speed, but there is an inevitable limit. In human activity, empires may often have swelled with dynamic rapidity, but a halt has always been called, sometimes from internal disruption, sometimes by external defeat. There is a limit to the size of a skyscraper, of an ocean liner and of an aircraft. To take the ocean liner, for example, in 150 years the size of ships increased from 1,000 tons to 83,000 tons — the size of the *Queen Elizabeth*. Marine engineers state with confidence that it is unlikely that any larger ship will ever be built, and, moreover, they have found smaller ships to be more efficient.

A hundred years ago the demand for electric power was a negligible factor in human affairs. Now, it is one of man's most pressing problems. If the rate of rise of demand continues to increase, by a *reductio ad absurdum* argument, the demand will become so great that the whole of the energy provided by the sun, the prime source of all our energy, will be needed to satisfy man's energy needs; and at this stage either perpetual motion will have been invented, or man will have altered his way of living so that his energy demand, like his ships, will have been stabilised at a reasonable limit. That time is obviously far in the future; there are very large reserves of water power still unharnessed, and the rapid progress now being made in high-voltage transmission practice means that wherever they exist the resulting energy can, at any rate in principle, be brought to wherever it is needed.

Water power provides man's oldest means for

taming nature to give him mechanical power, but it is only since the days of Faraday, a century and a quarter ago, that water power could break out of the limit which seemed inescapable—the need to use the power on the very spot where the stream turned the waterwheel. There still remains the almost incalculable amount of energy inherent in the diurnal swing of the tides and, within the next century perhaps, overtopping even this great store, comes the energy derived from nuclear fission.

In spite of these reserves, it is a sobering thought to realise that a continuance of the present rate of increase of world energy consumption will mean that no programmes of making more generating plant available, hitherto propounded by any Supply Authority anywhere, can possibly be regarded as providing a guaranteed freedom from power-usage restriction at any foreseeable time in the future.

"Power" Politics

THE St. Lawrence Seaways scheme appears to be one of those matters, all too common in the postwar world, where the technical issues involved have become entirely obscured by political matters bearing no relation to the real merits or demerits of the scheme itself. In 1948 we heard that the province of Ontario was planning to proceed at once with the development of power in the international rapids of the St. Lawrence river, and that agreement had been reached with the State of New York. At the end of the year, it seemed that President Truman was opposed to the plan; and we also gathered that the opponents of the scheme were trying to get the American steel industry to back their opposition measures. New schemes were put forward at the end of 1948 and in the early months of 1949, in which navigational facilities were incorporated, to meet the objections of Senator Wiley and others. Legislation was about to be introduced in the Senate to authorise the project.

From the Canadian side, every leading figure in the power industry urged speed in commencing the St. Lawrence scheme; but by the summer of 1950 we were again hearing of Mr. Truman's determined opposition. The Canadian Prime Minister said that his people were getting impatient at the delay. Then in 1951 we find that President Truman, and many other American statesmen, have changed sides. *The Times* of January 17 mentions that the President feels that "an entirely new and special urgency exists for the construction of the St. Lawrence Seaway and Power Projects." Canadian hopes were raised much higher; but in May it seemed that these hopes were premature. The Canadian authorities were proposing to proceed alone. As late as November 1951 we hear that President Truman still favoured a joint project, but would support independent action by Canada if joint action were impossible.

The latest firm news concerns the agreement signed in Ottawa between the Federal Government and the Provincial Government of Ottawa, regarding the latter's share in the Canadian Seaway project, coupled with a further appeal last month by President Truman to Congress for approval of U.S. participation.

As with the Severn Barrage in Great Britain, the Seaway has been built many times over on paper; perhaps one day the pick will take the place of the pen.

River Erne Progress

THE first generating set on the river Erne, Cathaleen Fall hydro-electric power station, was brought into commission on November 27. This 22,500 kW turbine is capable of an annual output of 75 million kWh and is expected to help considerably toward meeting peak demand. With Erne Cliffe station already in partial operation the combined annual output of this scheme is now 100 million kWh or half of its expected total output upon completion in 1954. It is hoped to have a second 22,500 kW generating set at Cathaleen Falls in operation by June 1952. Another generator (10,000 kW) on order for the Cliffe station is scheduled to commence operation in 1954 and so complete the initial development of the river Erne. Although the scheme will produce 200 million kWh of electricity a year there will be a limitation on the use of the station for a few years until completion of the water storage developments on Lough Erne in Northern Ireland. The work is being carried out under agreement between the Northern Ireland Ministry for Finance and the Electricity Supply Board at a cost of £750,000.

Developments in the Philippines

THE recent news that a $20,000,000 loan has been made by the Export-Import Bank of the U.S.A. to the Philippine National Power Corporation shows that the United States have every confidence in the industrial future of the country. An important factor in this aspect of the Philippine economic system must be the intense hydro-electric development now taking place, even if many of the plants are of a relatively small size. On Bohol Island, the Loboc plant, of 500 kW, is almost completed.

Among the largest developments are those on the Agno river at Abuklao, for which the loan mentioned above is specifically required. The plant here will be of 175,000 kW capacity. A 25,000 kW project is under construction at the Maria Cristina falls, on the Mindanao river, where the power will partly be used for the production of fertilisers. Other schemes on the Talomo river and at the Tontonan falls are being pressed forward. A total of 8,000 kW of small plants is in the course of planning or under construction.

Orange River Conservation Dams

THE South African House of Assembly debated recently a motion which asked the Government to consider the advisability of building a series of conservation dams across the upper reaches of the Orange river and its tributaries in their upper catchment areas, and of erecting a hydro-electric scheme on the Kraai and Orange rivers. The Minister of Lands and Irrigation, Mr. J. G. Strydom, said that a few years ago it had been estimated that the whole Orange river scheme would cost £70,000,000. It could be accepted that in present conditions it would cost more than £100,000,000. In pursuance of the Government's policy of developing irrigation schemes where the need was greatest, he had decided to place the Bushman's and Modder river schemes on the Estimates. Mr. Strydom said he had no doubt that when the smaller schemes which he favoured had been com-

pleted, capital would be available to finance the larger projects and the Orange river scheme would then have priority.

Figures showed that in the last four years the Government had allocated half as much money for irrigation as had been allocated in the 38 years between 1910 and 1948. As the country's food requirements increased, future governments would be obliged to spend more and more on water conservation. In this respect the present Government had done its duty. Mr. Strydom said the silt problem in the Orange river was very serious and unless a solution could be found, any large dams built on the Orange would soon silt up. Moreover, though the Orange river scheme would have to be tackled sooner or later, it was impossible to consider such a large undertaking at this stage. It had to be borne in mind that three-quarters of the water of the Vaal was still unused and that east of the Drakensberg several large rivers with a far lower silt content than that of the Orange were still undammed.

Pacific Coast Developments

OUTSTANDING new developments on the U.S. Pacific coast include the McNarry plant with fourteen 70,000 kW units and Chief Joseph plant with twenty-seven 60,000 kW units, both on the Columbia river in the north, and three 37,500 kW fully automatic outdoor plants on the Owen river in the south. Automatic tie-line load control over long distance has reached a high stage of development during the past year and made possible greater conservation of available power. Subnormal and off-season precipitation on the Pacific coast has seriously interfered with hydro-electric plant operation and led to unprecedented expansion of thermal generation. The most outstanding development in the hydro-electric field was the initiation of construction on a hydro-electric power plant in Canada which will have an ultimate firm capacity of 1,200,000 kW in ten multiple-nozzle vertical Pelton-wheel generating units. These units will operate at the head of approximately 2,600 ft. Generating equipment and transformers will be installed in an underground power house with output fed to an outdoor switching station.

The Kundah Hydro-Electric Development

THE development of a head of 2,800 ft., second only to the head of 3,080 ft. available at Pykara in three or four stages to produce 150,000 kW of hydro-electric power at a total cost of about Rs. 20 crores is the main feature of the largest and most promising scheme in the Madras State. Called the Kundah Hydro-Electric Development, the final investigations have been completed. According to official sources the scheme is included in the Second Five Year Plan of Power Development in the State and will be taken up as soon as funds permit. The scheme envisages the conservation of the waters of practically all the major streams running down the south and western slopes of the Nilgiris, including the Kundah and Avalanche rivers, by the construction by stages of six reservoirs to develop the full potential. It will be nearly twice as large as the Pykara Hydro-Electric development from the point of view of power production.

In the first stage, it is proposed to develop 50,000 kW with a power house at Kil-Kundah and penstocks built down the Thiashola gorge. The second stage will go up to 75,000 kW and the third stage to 100,000 kW with additional pipelines. The tail water, before it flows into the upper reaches of the Bhavani river, will again be utilised at a convenient point in a similar manner to the Moyar scheme, which utilises the Pykara tail waters, and power to the extent of another 50,000 kW will be developed utilising a head of another 1,000 ft. As the textile industry in the nearby industrial area of Coimbatore has reached saturation point, the power developed will be employed in the development of other heavy industries.

According to the engineers who investigated the scheme, the Nilgiris offered further possibilities of power development other than the Pykara and the Kundah sites. As a matter of fact, the whole of the Nilgiris slopes could be converted into a series of hydro-electric power stations utilising the streams which flow out of this great natural source of water power on the lines of the Scandinavian countries and Switzerland.

Tokyo Power Company's Five-Year Plan

THE Japanese construction ministry announced at the beginning of 1951 a 15-year project of irrigation and power generation. The plan envisaged the construction of 36 dams in the initial stage. News from Japan now shows that two of the smaller projects have been put into operation by the Tokyo Electric Power Generation Company. These are situated in the Gumma Prefecture, which is about 100 miles north-west of Tokyo, and form part of that company's five-year plan for the production of a total of 37,920 million kWh per annum by 1953. The power is to be transmitted from these and other projects to the capital by means of 250 kV main transmission lines. The five-year plan, which is integrated with the overall 15-year scheme, includes the exploitation of 93 new sources of hydro-electric power.

Siam's Chainat Project to be Inaugurated

SIAM (Thailand) is yet another country where increased industrialisation has led to a re-survey of all the available hydro-electric resources. In 1948 an agreement was concluded by the Siamese Government with the General Electric Company of America for a survey of a number of possible sites for hydro stations. A mission from the World Bank investigated four such schemes in 1950.

One of the principal schemes is the Chainat project, on the Chao Phy river, some 100 miles from the capital. Now comes news that the Government have reached agreement with the World Bank on the inauguration of this project, which will also irrigate 2,500,000 acres of central Siam.

Tothill Press Bristol Office. Tothill Press Limited, the company owning this journal, has opened a branch office at 8 Upper Berkeley Place, Clifton, Bristol.

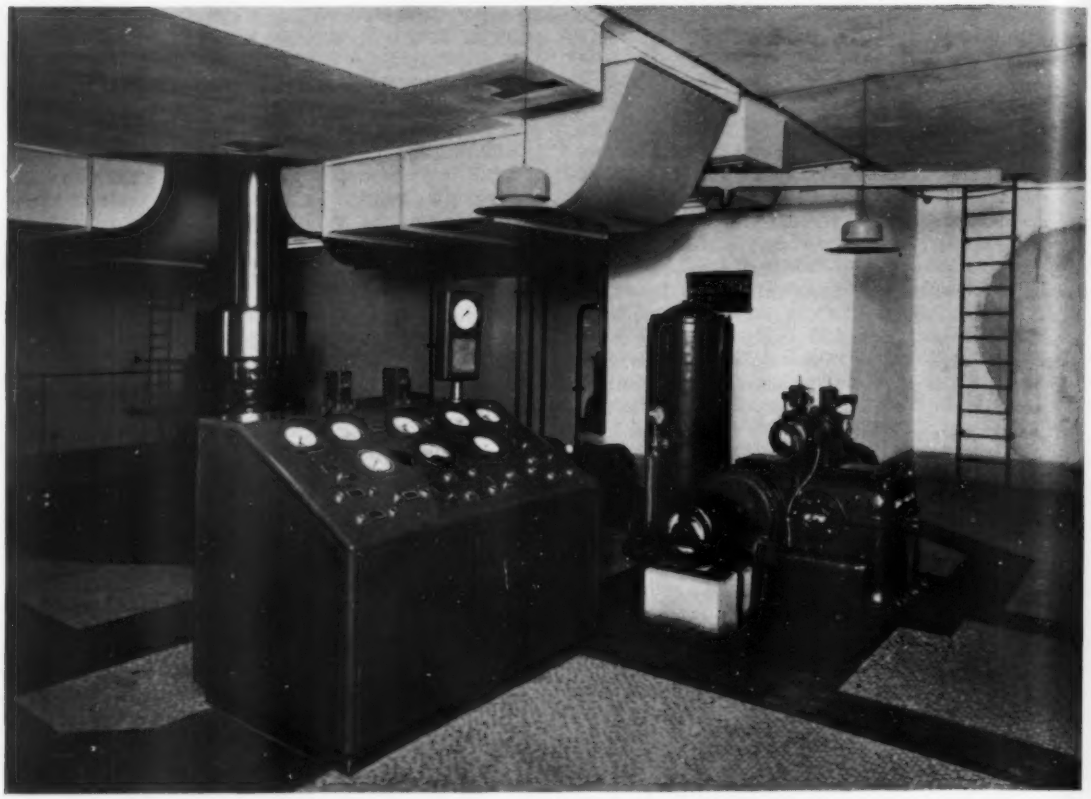


Fig. 9. One of the 55 MW turbines built by Costruzioni Meccaniche Riva

Soverzene Generating Station

In this article Dr. Ing. Mario Mainardis, Chief of the Generating Station Department, Società Adriatica di Elettricità, Italy, describes some of the chief features of the Soverzene power station, which forms part of the Piave-Boite-Vajont scheme.

PART TWO

NOW that an outline has been given of the Piave-Boite-Vajont scheme and the special features of the Soverzene station have been described, we can proceed to give details of the power plant and of the protective arrangements. Specifications of the equipment are as follows:

Hydraulic turbines

Type: vertical Francis.

Net head: maximum 284 m. (931 ft. 9 in.), medium 252 m. (826 ft. 9 in.), minimum 202 m. (662 ft. 9 in.).

Rate of flow: maximum 22 cu. m. per sec. (777 cusecs), medium 20·75 cu. m. per sec. (730 cusecs), minimum 18·6 cu. m. per sec. (667 cusecs).

Output: maximum 54·5 MW, medium 46 MW, minimum 32·4 MW.

50 cycle speed: 428 r.p.m.

Runaway speed: 800 r.p.m at maximum head.

Guaranteed efficiency: varies as a function of head; at nine-tenths of maximum output it ranges between 89·5 and 91 per cent.

Two of the three turbines so far installed were manufactured by Costruzioni Meccaniche Riva (Fig. 9) and the third by De Pretto Escher Wyss; they have cast-steel scroll casings and stainless-steel guide vanes and runners. There are two separate overspeed tripping devices, which close the wicket gate and the rotary inlet valve when overspeed reaches 25 per cent. of normal operating speed. The second device had to

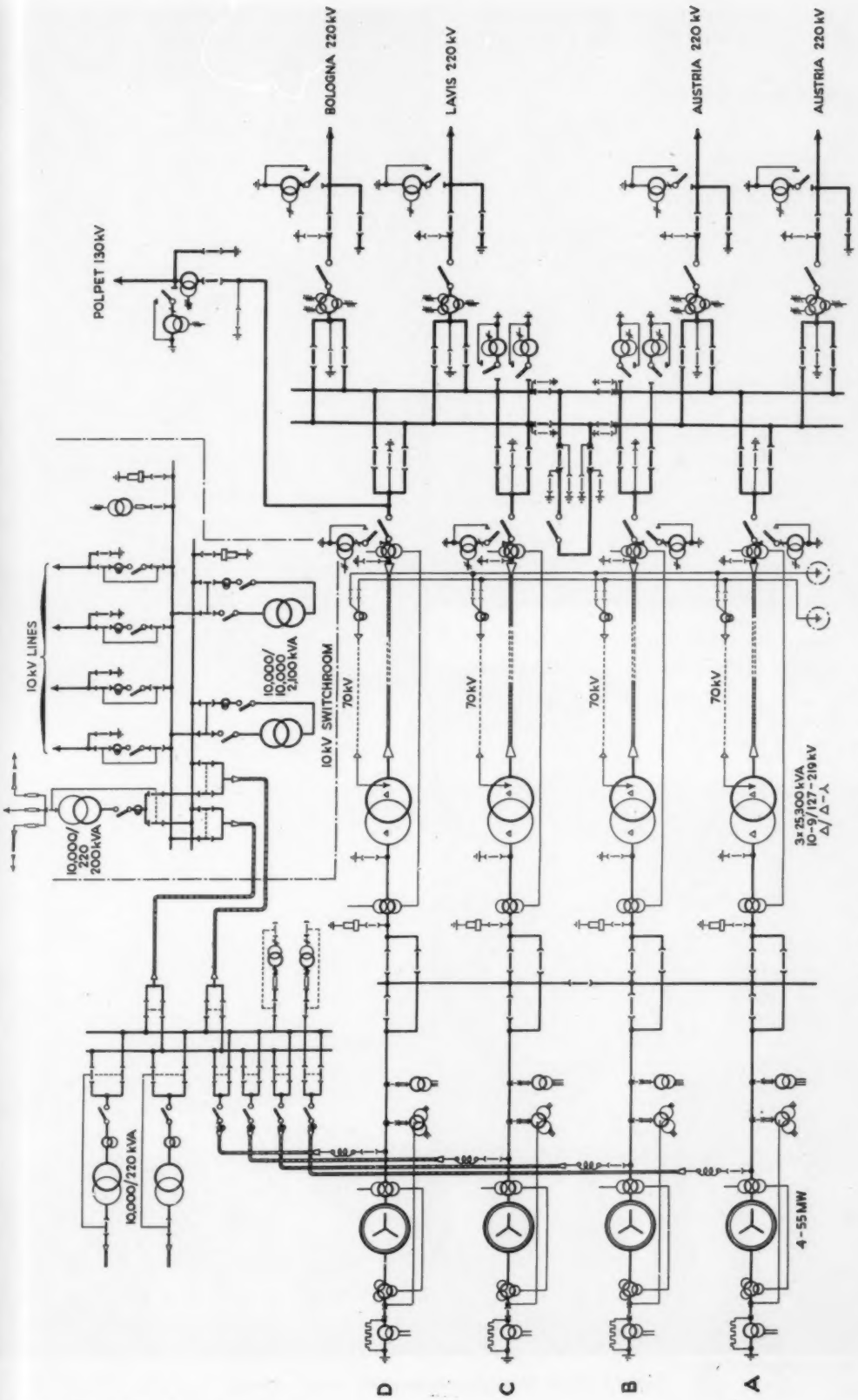


Fig. 10. Electrical circuit diagram for Soverzene power station

be installed for technical reasons because it was not possible to test the rotor of the main a.c. generator at runaway speed.

Three-phase main generators

Vertical.
Rated capacity: 60 MVA.
Rated current: 3,460 A.
Rated voltage: 10 kV + 10%.
Rated 50 cycle speed: 428 r.p.m.
Rated output: 55 MW at 0·92 p.f.
Self-excitation reactive capacity: 78·2 MVAR.
Flywheel effect: 1,400 t.m². (33,100,000 lb. ft.²).
Short-circuit ratio: 1·30.
Per unit synchronous reactance: 0·785.
Per unit transient reactance: 0·26.
Per unit subtransient reactance: 0·15.
Per unit negative-sequence reactance: 0·17.
Efficiency at full load and unity p.f.: 0·9844.
Efficiency at full load and 0·92 p.f.: 0·9825.

The generators were built by Ercole Marelli, and are provided with complete damper windings, designed to carry continuously a negative-sequence current equal to 30 per cent. of rated current, in order to eliminate dangerous over-voltages which might arise from unsymmetrical short circuits and to ensure a high damping of oscillations even at no load or light loads.

Transformers

Each set includes three single-phase units of the following specifications:
No-load transformer ratio: 10/138·6.
Continuous rated capacity at 10 kV primary voltage: 25·3 MVA.
Continuous rated capacity at 9 kV: 22·8 MVA.
Continuous rated capacity at 11 kV: 26·9 MVA.
Efficiency at full load and 0·92 p.f.: 0·991.

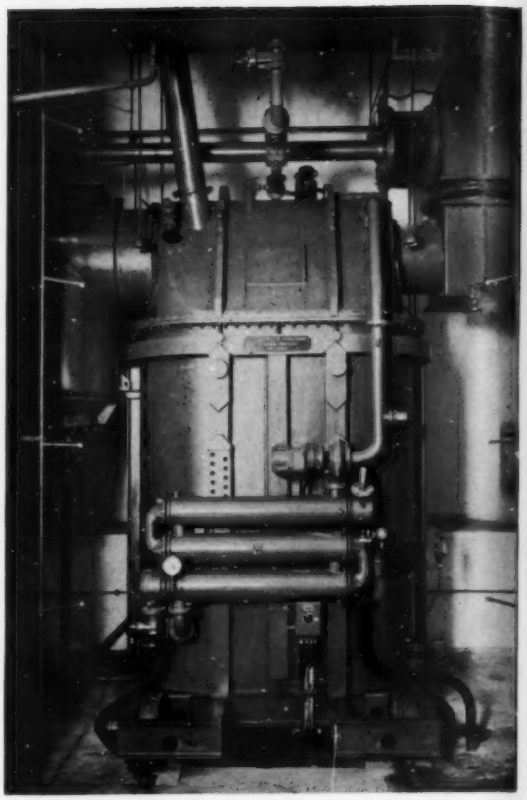


Fig. 11. A 25 MW single-phase transformer built by Tecnomasio Italiano Brown Boveri

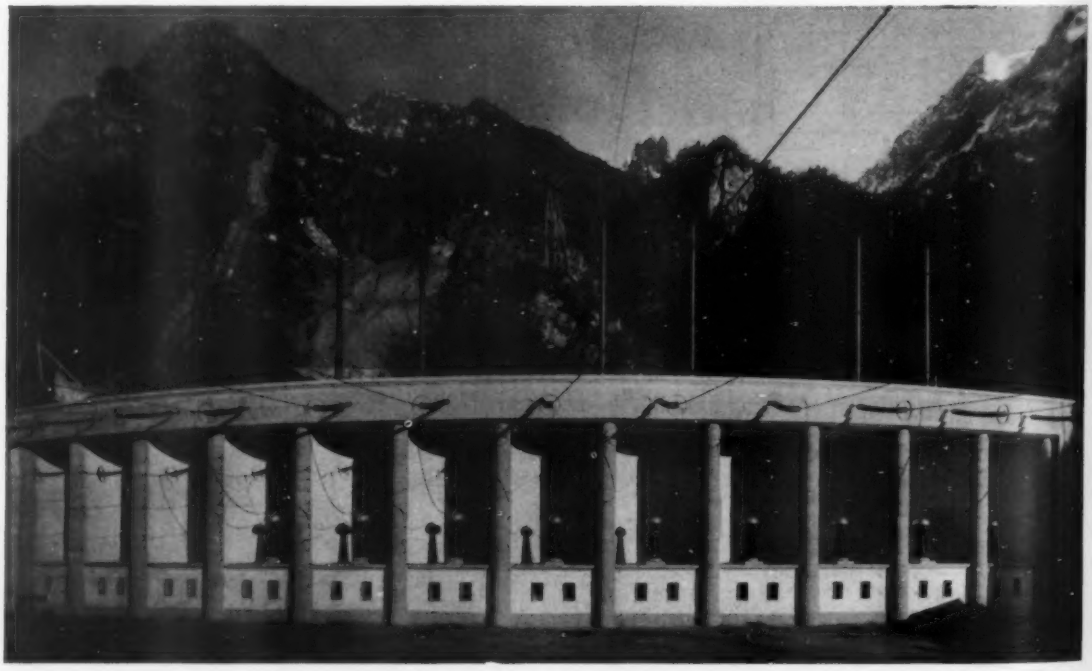


Fig. 12. 225 kV single-phase cable outlet (Pirelli)

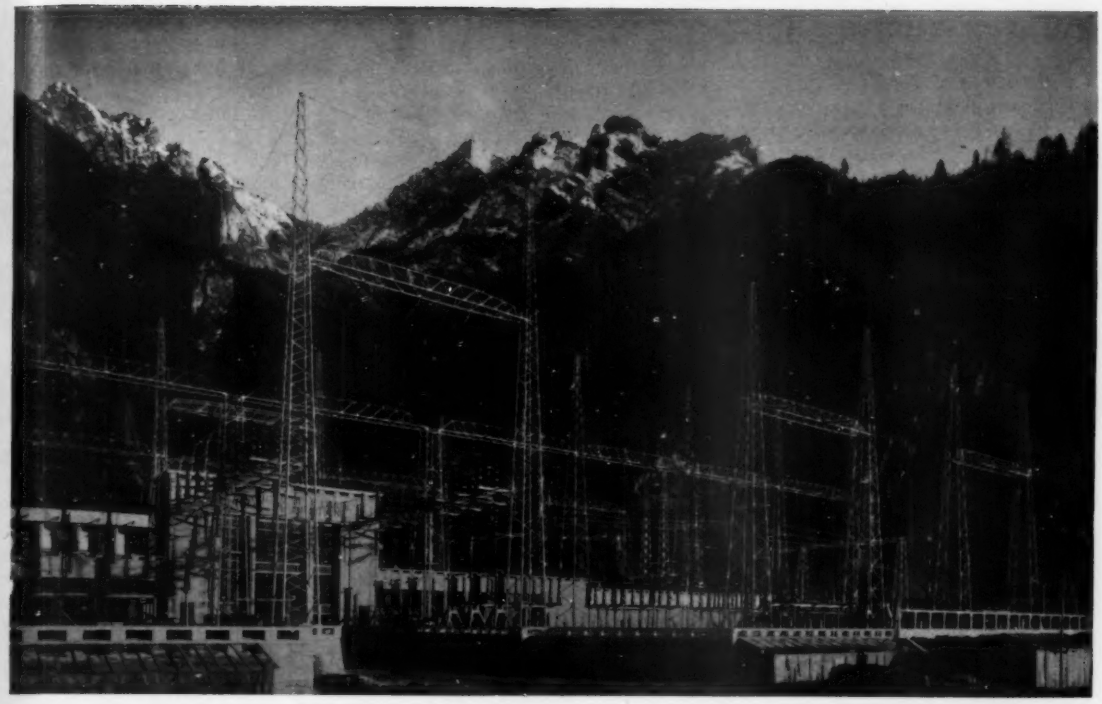


Fig. 13. A view of the 220 kV outdoor switching station

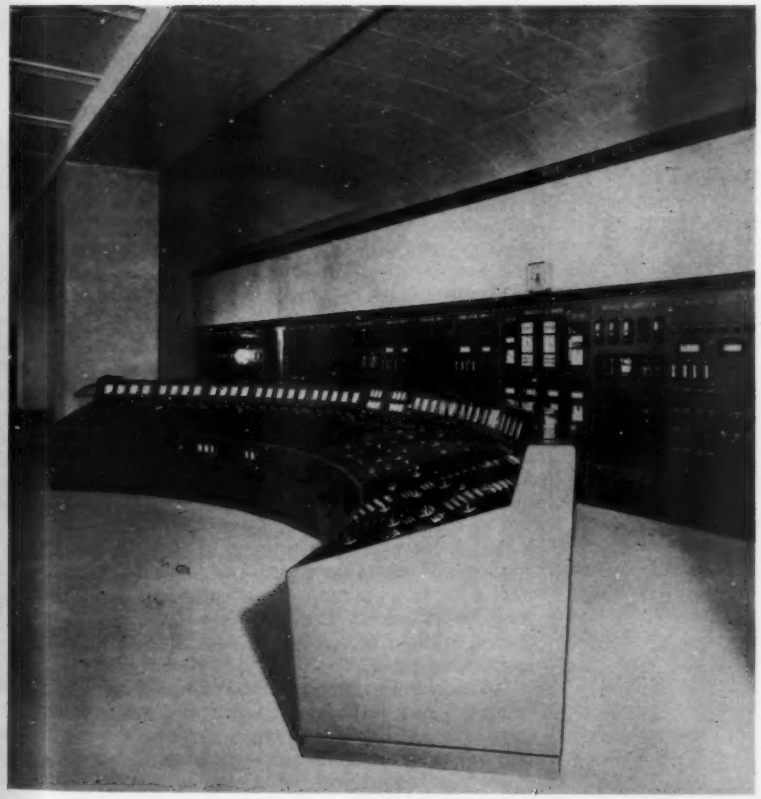


Fig. 14. The Soverzene control room equipped by Officine Galileo

Cooling of the transformers is on the forced-oil forced-water system with external coolers.

The 10 kV connections are by normal bushings, while 225 kV connections are by single-phase oil-filled Pirelli cables, placed on the false arch above the entrance tunnel, which is ventilated and matches the architecture of the power house.

The neutral of the transformer sets is brought out through an 80 kV single-phase cable, placed near the 225 kV single-phase cables, in order to minimise the circuit reactance.

Switchgear and electrical equipment

Electrical equipment (Fig. 13) furnished by Officine Galileo comprises:—

10 kV air-blast circuit breakers.
225 kV low-oil-content circuit breakers.
Compressed-air remote-operated disconnectors.
Instrument and control boards.

Protective equipment

The electrical protective

equipment (Fig. 15) for protecting the main a.c. generators and the transformers against internal and external faults consists of the following devices:—

Compensated differential protection (for phase-to-phase faults).

Unbalance protection (for turn-to-turn faults).

Stator and rotor earth protection.

Permanent overload protection by means of the "thermal image" relay.

Over-voltage and over-current protection.

Protection from short-circuits in the conductors connecting generators to transformer sets (by means of a minimum impedance relay).

Buchholz relay for transformers.

The differential, turn-to-turn and stator-earth protective devices operate a locked tripping device which, besides tripping the circuit breaker and the demagnetiser, closes the rotary inlet valve and the wicket gate, whereas the other devices only cause the circuit breaker and the demagnetiser to trip. As regards lightning surges it was deemed sufficient to protect the 225 kV outdoor substation by means of a net connected to the earth wires of the transmission lines.

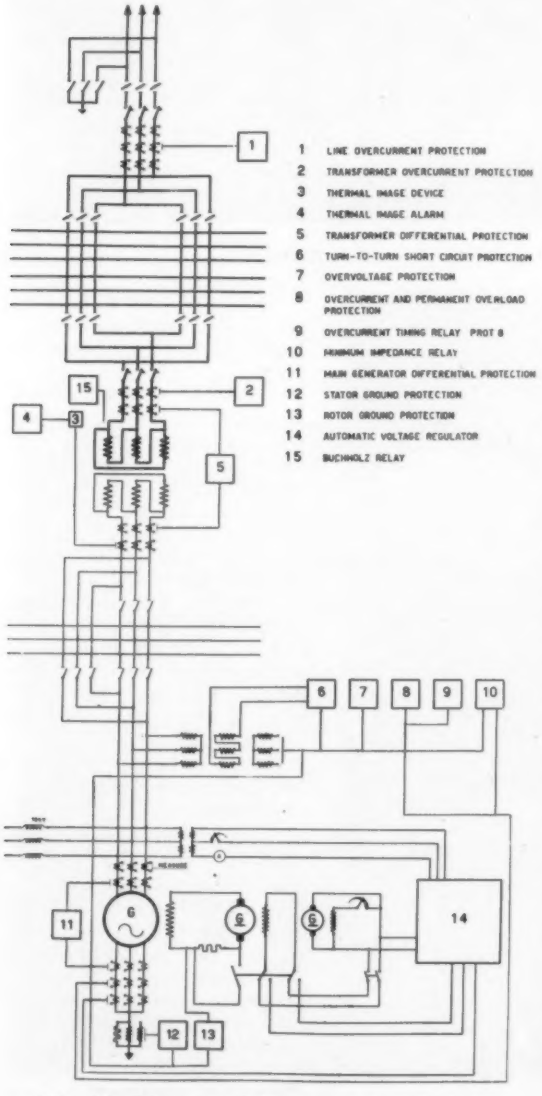

1 LINE OVERCURRENT PROTECTION
2 TRANSFORMER OVERCURRENT PROTECTION
3 THERMAL IMAGE DEVICE
4 THERMAL IMAGE ALARM
5 TRANSFORMER DIFFERENTIAL PROTECTION
6 TURN-TO-TURN SHORT CIRCUIT PROTECTION
7 OVERVOLTAGE PROTECTION
8 OVERCURRENT AND PERMANENT OVERLOAD PROTECTION
9 OVERCURRENT TIMING RELAY PROT 8
10 MINIMUM IMPEDANCE RELAY
11 MAIN GENERATOR DIFFERENTIAL PROTECTION
12 STATOR GROUND PROTECTION
13 ROTOR GROUND PROTECTION
14 AUTOMATIC VOLTAGE REGULATOR
15 BUCHHOLZ RELAY

Fig. 15. Diagram of the protective circuits

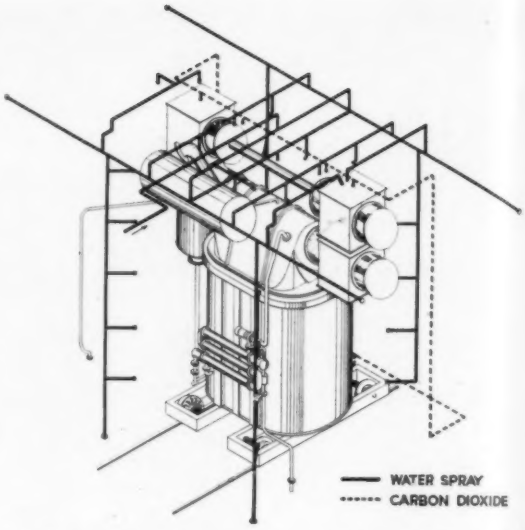


Fig. 16. Diagram of the fire-protection equipment for one of the transformers

Auxiliary services and fire prevention

Two independent plants for fire prevention and protection of the generators and transformers are provided, one with carbon dioxide, for both generators and transformers, and the other with atomised water jets for the transformers alone (Fig. 16). The double protection for transformers was suggested by the damage which might be caused by a possible fire in consequence of the underground location.

The carbon dioxide plant, manufactured by Bergomi, comprises two eight-bottle systems, each having sufficient capacity to protect one transformer cubicle and keep an ambient saturation of 30 per cent.

The operation of the CO_2 plant is automatic and is controlled by heat-sensitive elements installed in the generator cooling circuits and in each transformer cubicle. When the fire-prevention plant is started up the air intakes in the rooms where carbon dioxide is injected are automatically and tightly closed. Each system of bottles includes a slow-discharging bottle, which keeps up the ambient saturation, making up for any gas losses which might occur through possible openings.

The atomised-water plant, built by Officine Galileo, includes, for each transformer, 33 atomising nozzles, so disposed round the transformer that, in case of fire, it is completely wrapped by water fog, and the fire quickly smothered. The operation of the plant is controlled by eight heat-sensitive elements disposed within each cubicle.

As soon as the temperature in a transformer cubicle or in a generator begins to rise, not only the extinguishers, but also the alarm lights and horns on the control board and the locked tripping device are operated, so that normally there is time for the unit to be put out of service before the discharge of carbon dioxide or atomised water begins.

Lighting

The vastness of the rooms and the need for high lighting levels suggested the adoption of indirect lighting by means of fluorescent lamps. Both on aesthetic and psychological grounds, the lamps for the generator room were installed in niches behind large dummy windows. These are placed on three of the four walls, so that a homogeneous lighting effect is achieved, giving the gratifying impression of sunlight coming through the windows.

The control room is lit by a row of fluorescent lamps placed on the girder of the glass wall dividing it from the generator room so avoiding any reflections on the glass panels of the control desks.

Lighting of the entrance tunnel is also by means of fluorescent lamps, spaced in such a way as to create a succession of bright arches giving a pleasing effect of perspective.

Ventilation

Fresh air from the exterior is brought in through the false arch of the entrance tunnel, at the end of which it is divided into five parallel branches for the ventilation of the generator room, transformer cubicles, generators, the control room and battery room. After passing through these rooms, the air is taken to the false arch and the air gaps of the generator room and withdrawn by means of a centrifugal suction fan placed at the intake of the exit adit.

Two centrifugal fans are provided in the generator room and the battery room to create a brisk air circulation. In the control room an air-conditioning plant is installed which keeps mean air conditions at 22°C. (71·5°F.) and 65 per cent. relative humidity.

Flood protection

At the intake from the Pieve di Cadore reservoir two butterfly valves with automatic overspeed closing equipment are provided in order to minimise any damage from possible faults in the pressure tunnel. Two further automatically closing butterfly valves are also placed in the tunnel from the Boite reservoir, the one upstream and the other downstream of the canal bridge of the Piave river.

Provision is also made for the automatic closing of the sluice immediately upstream of the outlet of the pressure tunnel to the Val Gallina reservoir. Finally, two butterfly valves are installed at the inlet of each pipeline, one of each pair being equipped with an automatic overspeed closing device. All safety valves can also be closed from the control board.

To avoid flooding of the power house in the event of a burst in the lower part of the pipelines, or of the turbine casings, the brick walls between the turbine compartments and the tailraces were built weak enough to break down as soon as even a slight water head arises in the turbine compartment. Watertight doors are provided between the turbine compartments; they are designed to withstand the maximum head expected in case of flooding, so as to confine the flood water to the actual turbine compartment concerned. These doors are normally open in order to allow the service personnel to move quickly from one compartment to another, but as soon as flooding begins the two doors separating any of the turbine compartments are automatically closed by a floatbox placed in the lower part of the room.

Navy-type safety ladders allows the personnel to reach the busbar room above without loss of time.

Book Reviews

A Bibliographical Survey of Flow through Orifices and Parallel-Throated Nozzles.

By T. H. Redding, M.Sc. (Lond.), A.M.I.Mech.E., A.F.R.Ae.S. Chapman & Hall Limited, 37 Essex Street, London, W.C.2. 1952. 199 pp. 31 ff. 3 tt. Price 32s. 6d. net.

This bibliography is a research publication of the British Scientific Instrument Research Association, and is concerned with the use of orifices and parallel-throated nozzles for measuring the flow of liquids and gases. As the title indicates, venturi meters are not included. The bibliography aims to cover the bulk of the relevant literature published between 1832 and 1946, and contains over 600 references under 16 subject headings. Each reference is accompanied by a brief summary of its subject matter. The bibliography is prefaced by an 18-page technical introduction, and amongst the appendices is a list of definitions of over 90 terms used in connection with flow measurement.

The Design and Placing of High-Quality Concrete.

By D. A. Stewart, A.M.I.C.E., A.M.I.E.E. E. & F. N. Spon Limited, 22 Henrietta Street, London, W.C.2. 120 pp. 40 ff. 1951. Price 25s. net.

Evidently the author of this book is not only a specialist but an enthusiast, and he has no use for the empirical methods that obtain all too frequently in the making and placing of concrete. He contends that by applying scientific principles to the design of the mix and to its treatment, concrete of far better quality can be obtained than is now current except in a few specialised fields. After discussing the interrelationship between the principal characteristics of concrete, the author pays considerable attention to the assessment of workability—a subject on which he has done much original work. Batching and mixing come in for some critical comments; weight batching is the only method considered tolerable for high-quality work, and several popular types of mixer are criticised on the ground that they tend to segregate the mix. Compaction by means of vibrators is treated in detail, as the correct application of vibration is evidently considered essential to the production of high-quality material. The author then proceeds to discuss the theory and method of mix design, reviews contractors' problems in placing vibrated concrete, and concludes by suggesting a method of specifying concrete which is designed to meet objections advanced to the existing form of specification. A foreword to the book has been contributed by Dr. W. H. Glanville, Director of Road Research.

Fifth Hydraulics Conference at Iowa

Transportation of sediment has been chosen as the theme of the Fifth Hydraulics Conference to be held at Iowa City, Iowa, June 9-11, 1952. This series of triennial conferences is sponsored by the Iowa Institute of Hydraulic Research of the State University of Iowa. Topics of the six half-day sessions will include problems of laboratory and field measurement; sedimentation in canals, rivers, estuaries, and harbours; and a tour of the Institute laboratories.

Some Lesser-known Aspects of Flow Measurement

A. Linford, B.Sc., A.M.I.C.E., A.M.I.W.E. discusses a number of practical design factors that have a bearing on the choice of metering equipment for large flows in both closed conduits and open channels.

ALTHOUGH in recent years great strides have been made in that branch of engineering commonly referred to as instrumentation, only limited steps forward have been made in the development of primary elements used for metering fluid flows.

For measuring the quantity of flow through both small and large conduits, the only method which has a universal application is still that which relies on the generation of a differential pressure, notably the orifice plate and the venturi tube.

In the case of open-channel liquid-flow measurement, in addition to the familiar weir, of which there are a number of standard patterns, the venturi flume, also known as the standing-wave flume, has become well established within the last twenty-five years as a metering device.

No mention is made here of current meters, "mechanical" meters and the like, since their application is strictly limited. Thus, the former class of instrument is used for occasional tests and rating purposes, while the latter can only be used for metering flows through relatively small pipes.

When the problem of metering fluid flows arises, as it does in all branches of engineering, there still appears to be a number of misconceptions among engineers not specialised in this particular art, as to what can or cannot be done. The purpose of this article is to consider the lesser-known aspects of this branch of instrumentation. The following notes, where they refer to closed-conduit flow measurement, in most instances are also applicable to gases as well as liquids, but the prime object is to consider liquid-flow measurement, and, of course, by far the most important liquid is water; sewage may also be classed under this heading.

Measurement in large closed conduits

The first problem to be considered is that of measuring flow with the minimum head loss through large closed conduits. The general conception here seems to be that any form of differential-pressure generating device always causes an appreciable head loss and is very expensive, but neither of these statements is strictly accurate. Of course, the differential-pressure generating device which causes the least head loss is the familiar venturi tube with a long recovery cone on the downstream side. Providing velocity conditions are within certain limits, it is not difficult to design a suitable venturi tube having a throat ratio of such a value that the net head loss through the device is less than 10 per cent. of the differential head generated (vide British Standard Code B.S. 1042:1943) and satisfactorily to operate a standard form of differential pressure-measuring instrument for registering the rate of flow; a maximum differential head of 20 in. w.g. or even less may be used. Assuming a maximum differential head of 20 in. and a head loss of 10 per cent., only 2 in. w.g. will be lost through the meter at the maximum rate of flow, and this cannot be regarded as excessive.

In passing, it may be mentioned that the "horsepower" of a flow meter, i.e. the horsepower absorbed on account of its installation, can be expressed in the form, $H.P. = 0{\cdot}113\,QH$, where Q is the rate of flow in cusecs, and H is the net head loss in feet w.g. In the instance of a pumping main, the meter "horsepower" can be capitalised and compared with the capital cost of various forms of differential-pressure generators, e.g. an orifice plate and a venturi tube with a short pressure-recovery cone. An optimum value can then be found beyond which a venturi tube with a long recovery cone, notwithstanding its extra cost, becomes in the long run a more economic proposition than installing a less costly differential pressure generator which absorbs more horsepower.

At this juncture, it is desirable to define the exact meaning of the term "net head loss" through a venturi tube. The word "net" is used to show that this is the extra loss caused by a venturi tube (or other differential-pressure generator) over and above the loss which would be caused by the same length of conduit which the venturi tube replaces. This may appear to be a small matter, but actually it is not so when a venturi tube with a long head-recovery cone and a small value of throat ratio, i.e. $\frac{\text{throat area}}{\text{upstream area}}$, is being used; an actual example may be quoted. A 40 in. diameter venturi tube with a throat ratio of approximately 0·5 generates a differential head of 18 in. w.g. at the maximum rate of flow of 25 million gallons per day. The venturi tube is 20 ft. long, this length including that of the downstream expansion cone, which has a cone angle of approximately 5° to give minimum head-loss conditions. At the rate of flow quoted above, the head loss was found to be 2·16 in. w.g., equal to 12 per cent. of the differential head. However, the net head loss resulting from the installation of the venturi tube was considerably less than this, since it was found that the head loss through a 20 ft. length of the 40 in. diameter pipe at 25 million gallons per day was 0·9 in. w.g. Therefore, the net head loss through the venturi tube, i.e. the extra loss resulting from its installation, was 2·16 in. – 0·9 in. = 1·26 in. w.g., or 7 per cent. of the differential head.

From the formula given in the foregoing, the "horse-power" of the meter at 25 million gallons per day just exceeds ½ h.p.

The Dall Tube

Until recently, a problem that has defied solution is the case where the velocity of flow through the conduit has been such that, with the specified head loss, it has not been possible to design a venturi tube to generate sufficient head to operate the recording instrument. This matter has occupied the attention of research workers for a considerable time, and, after many experiments, what is known as the Dall* tube has been produced. It has been named after the research worker who was mainly responsible for its development from an item of scientific interest to a practical commercial proposition. Its general features are that it has a discharge coefficient value of the same order as that for an orifice plate and the low percentage head loss of a venturi tube, yet its overall length is considerably less than that of an equivalent venturi tube with a short expansion cone. The effect of the first two features is that, approximately, the Dall tube will generate about double the differential head of a venturi tube having the same upstream diameter and throat bore with the same net head loss. The advantage of the reduction in length needs no comment.

*See WATER POWER, August 1951, page 315.

In principle, the Dall tube consists of two truncated cones, each with a large cone angle, the throat being formed by a circumferential slot contained between the two smaller diameters of the truncated cones. At present each application for the Dall tube needs individual consideration, and its use is limited to circular mains.

Non-circular conduits

The conventional form of venturi tube can be applied to a conduit of any geometrical shape, e.g. square or rectangular, and it may be constructed of the usual building materials instead of metal. In view of the limitless possibilities of different cross-sectional shapes for conduits, during the past half century the trend has been to concentrate on venturi tubes of square and rectangular cross section, in addition, of course, to venturi tubes for circular pipes which latter fulfil most industrial requirements and certainly all those where the conduit is small. As a result of this trend considerable practical information has been accumulated, and it has been proved conclusively that a venturi tube of rectangular cross section, for example, can be satisfactorily constructed in concrete, metal being used only for the critical throat section and for the upstream section. In the instance of a large conduit, by eliminating metal construction throughout, the additional capital cost of installing

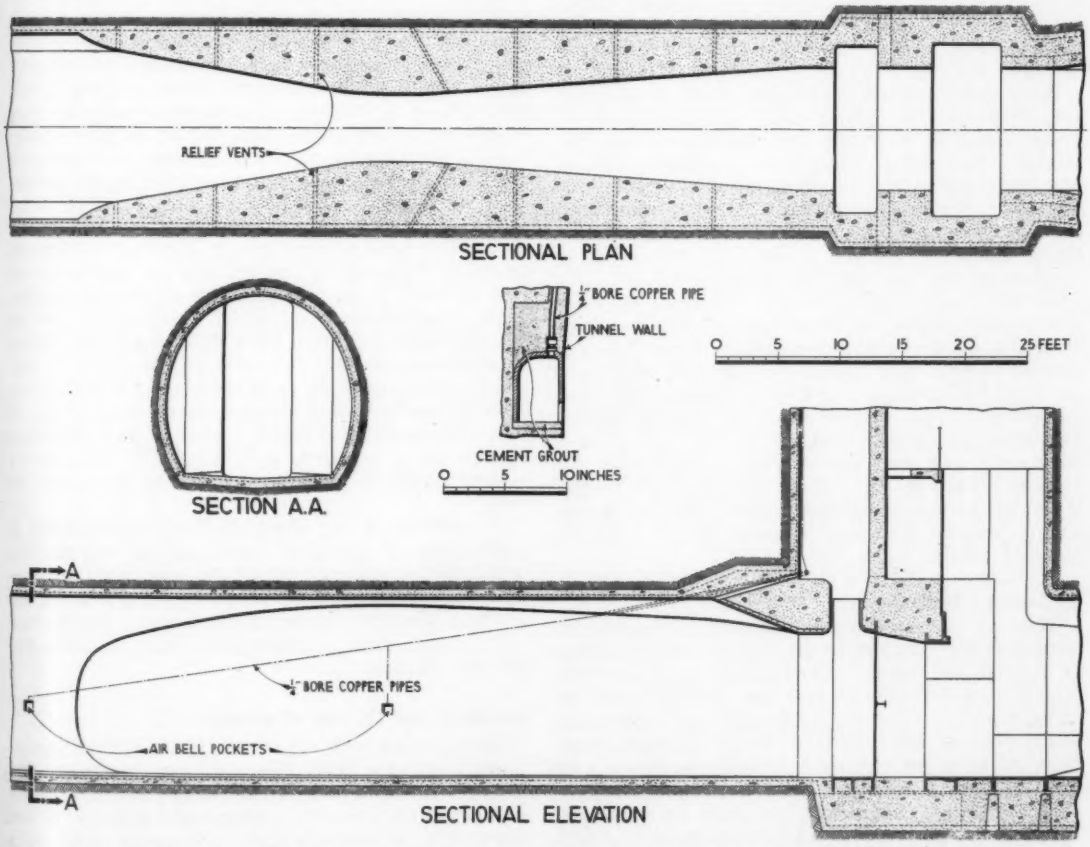


Fig. 1. Venturi and roller-gate section of a tunnel intake for a Scottish hydro-electric development (British Pitometer Co. Ltd.)

Fig. 2. Free discharge flume at the Burgh of Hamilton waterworks (George Kent Limited)

the meter is reduced to a relatively small amount, and the venturi tube becomes an attractive proposition. Here it may be pointed out that it is the standard practice to use side contractions only for venturi tubes of square or rectangular cross section, the top and bottom being parallel to each other throughout the length of the tube.

Rectangular venturi tubes have been constructed with only one side contraction, but in the author's opinion this is carrying the departure from the "classic" venturi-tube design to an extreme, and is not warranted by the small saving in constructional cost. The design is unsymmetrical, the differential head measured on the side without the contraction being smaller than the differential head obtained from tappings on the side with the contraction.

However, on rare occasions, circumstances do arise where a special design is imperative. To take an actual example, a new circular sewer of large diameter crossed an existing one practically at right angles and at a slightly higher level at a point where it was convenient to install a flow meter for measuring the discharge of the new sewer. This was too good a chance to miss, and the obstruction caused by the existing sewer was used to form the throat of a venturi tube, the necessary upstream approach and downstream expansion being formed by constructing concrete ramps.

Registering Instruments

The cost of the registering instrument is exactly the same whatever the size of the conduit or the volume of liquid to be metered. Flow-registering instruments are of standard design, and are manufactured for dealing with a wide range of maximum differential heads. The design procedure for a differential-head flow meter is to calculate the dimensions of the primary element so that it generates the nearest standard maximum differential head to that actually required on account of head-loss considerations. There are, however, two aspects which may increase the cost of the instrument. If an extremely low head loss is required or the conduit is under a low static pressure —and both the conditions are usually associated with each other—the maximum differential head may be lower than that permissible for one of the inexpensive forms of industrial instruments. The most familiar form of industrial instrument is of the mercury U-tube pattern, suitable for a lowest maximum differential head of the order of 20 in. w.g. Alternatively, due to a low static pressure, it may be found that the registering instrument must be placed above the hydraulic gradient. If the instrument is mounted in such a manner, trouble is inevitable on account of the formation of air locks in the metering system extraneous to the conduit.

The solution to both the sets of circumstances mentioned above is to use the water-column principle, where two chambers, open at the top to the atmosphere, are connected, respectively, to the upstream and throat tappings, and the difference in water level in these is measured by two large-diameter floats which actuate the recording mechanism through flexible metal cords and a differential gear. On occasions, displacers have been used instead of floats, the displacers being suspended on a beam carried on a knife edge. The additional cost of the installation is mainly on account of the cost of cast-iron float columns, together with the dry pit in which to house them. However, an appreciable saving in cost can be achieved by constructing the float chambers in concrete.

Attention may be drawn to the arrangement sometimes used of pneumatically transmitting the differential pressure to the registering instrument mounted above the hydraulic gradient. In its simplest form, this consists of injecting a small but continuous flow of air into each pressure pipe, the air escaping in the conduit through the pressure tappings, the upstream and throat pressures being transmitted to the instrument by the air. The instrument may be of the conventional mercury U-tube form, or, if the maximum differential head is very low, a form of instrument primarily designed for low-pressure gas measurement may be used. A typical instrument of this description is the ring-balance type, which is manufactured to give full-scale deflection for a differential head down to as low as an inch or two w.g. However, an "air reaction" system of the form described above involves the complication of a compressed-air supply, and it is recommended that when a really robust metering installation is required, with minimum attention by skilled labour, the water column principle should be used.

In addition to the above methods of obtaining a registration of the flow, there are, of course, the conventional forms of pneumatic and electric transmission, but the primary object of these is to afford a means whereby a record of the flow can be obtained at a point some considerable distance from the primary element.

Accuracy and the use of models

Having dealt with the matter of capital and operational costs of a large differential-pressure meter, the next point that naturally comes to mind is the question of accuracy. Since it is frequently difficult, if not impossible, to obtain a direct volumetric check on a large flow meter, what guarantee is there that the meter will register the flow passed with a tolerable

error? In the majority of cases a commercial tolerance of ± 2 per cent. over the higher flow range of the instrument is acceptable. The answer to this question was first established with certainty about 1916, when the principles of dynamic similarity were first applied to the hydraulic calibration of models of flow meters.†

Briefly, the discharge coefficient of a differential-pressure generating device will be identical with that of a geometrically similar model at the same value of a non-dimensional criterion universally known as the Reynolds number. The physical factors which constitute this criterion are, rate of flow in volume units, Q, the density of the fluid, W, the viscosity of the fluid, μ, and a linear dimension of the differential-pressure generator. The linear dimension is usually taken as the throat bore, which may be denoted by D. The expression takes the form $\frac{QW}{D\mu}$ and, of course, a consistent system of units must be used. To avoid confusion, the c.g.s. system is recommended, i.e. rate of flow in cubic centimetres per second, density in grammes per c.c., viscosity in poises and the linear dimension in centimetres. In the case of water metering, since water is also used as the medium for calibrating the model, the criterion is simplified to $C\frac{G}{D}$, where G is the rate of flow in say cusecs, and D is the bore of the throat, while C is a constant which includes all the factors common to the full-size meter and the model. Denoting the full-size meter by suffix a, and the model by suffix m, if the discharge coefficient is required at a flow G_a, then $Gm = G_a\frac{d_m}{d_a} = \frac{G_a}{s}$, where s is the model scale ratio. Since the differential head is directly proportional to the square of the flow rate, for any rate of flow G_a, at the equivalent rate of flow G_m, the differential head generated by the model will be s^2 times the differential head generated by the full-size meter.

For a correctly designed primary element, as the flow rate increases the discharge coefficient also increases, but the curve is asymptotic; the discharge coefficient attains a constant value above a certain rate of flow. The secret of good design is to ensure that within the flow range of the meter the discharge coefficient is constant. Under these conditions, model testing is very much simplified, it only being necessary to test at a few flow rates to demonstrate that the value of the coefficient does not change, and it is not necessary to take a large number of points as would be the case if a "coefficient curve" had to be ascertained.

The truth of the criterion for model testing has been demonstrated on many occasions by full-scale check tests on both large and small primary elements of all types, and, with the practical data accumulated, providing hydraulic conditions in the vicinity of the meter are satisfactory, model testing is only essential when a rectangular or circular venturi tube is of unorthodox design. A typical example where a model test was imperative was in the case of the "hump"-type venturi tube referred to in the foregoing.

In general, the statements already made are applicable to orifice plates and nozzles, but in view of head-loss considerations neither of these devices is really suitable for the metering of large flows of liquid.

†*vide* J. L. Hodgson. "The Commercial Metering of Air, Gas and Steam." (Proc.Inst.C.E. Vol. CCIV. Session 1916-17. Part 2).

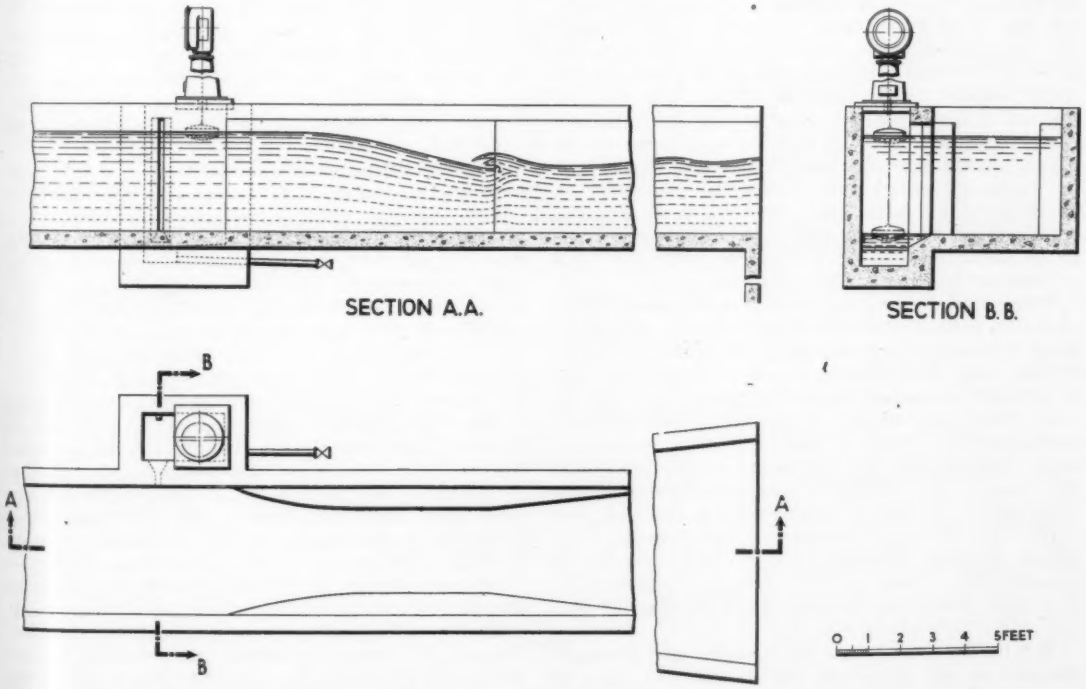


Fig. 3. A rectangular-section flume working in conjunction with a Kent transmitter

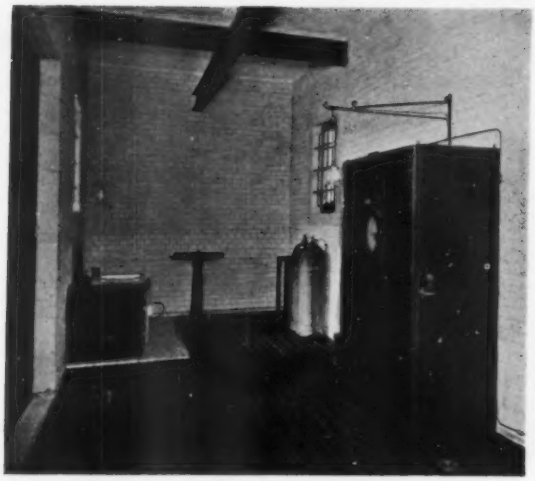


Fig. 4. Kent metering installation on the River Dee at Llantisilio (Courtesy British Railways Research Department)

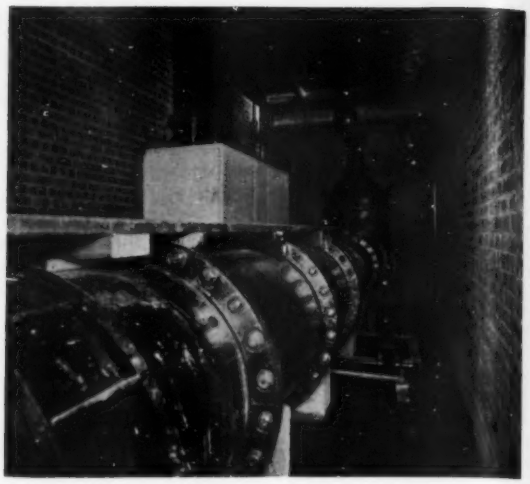


Fig. 5. The venturi-tube chamber at Llantisilio showing the two float columns and the downstream control valve

In fact, at the present time, there is a tendency towards utilising venturi tubes for metering low-pressure gases, it being found more economical to fabricate a venturi tube out of light metal sheet than to use an orifice plate and consequently increase the permanent head loss.

The Pitot Tube

Reference may be made to the use of the pitot tube for metering flows through large conduits. The disadvantages of the pitot-tube form of measuring device are that even if hydraulic conditions in the vicinity are exceptionally good, it is desirable to traverse the conduit to obtain a reliable relationship between the mean velocity and the velocity obtained at the tube tip, and it is necessary to assume that this ratio will remain constant under all working conditions. In addition, the danger of a blockage of the impact vent is always present, together with the possibility of breakage of the tube—this can quite easily occur if some foreign body is caught up on it. A case in point is the breakage of a pitot tube due to a long piece of seaweed wrapping itself round the tube.

When a pitot tube is proposed it is sometimes found that even in its double-tip form, insufficient differential head is generated on account of the natural velocity of flow, and this precludes its use in conjunction with a standard industrial registering instrument. In the case of metering volumes of gas flowing through large conduits, this problem of lack of head has been overcome by utilising what is known as the pitot-vent. In principle, this consists of a very small venturi tube fitted on to the end of a conventional form of pitot tube. The differential pressure measurement is obtained between a static pressure connection in the conduit and a connection in the small venturi tube. Practical difficulties prevent the utilisation of this device for liquid-flow metering.

It is hardly necessary to state that the very attractive features of the pitot tube are its low cost, ease of installation and, for all practical purposes, complete absence of any head loss.

Range of Registration

A question that sometimes arises in connection with differential-pressure meters is the range of registration. On account of the square-root flow law, normal commercial meters are limited to a range from maximum flow down to one-eighth or one-tenth of this. This is usually sufficient for industrial purposes, but in waterworks and sewage practice a longer range is sometimes required. To satisfy this demand, special instruments have been developed which are operated by floats of a larger diameter than those used in general industrial meters. In addition, to enable the flow record to be legible over the lower range, large rectangular charts are used. By this means, a flow range of something in the region of down to one-twentieth of the maximum designed flow rate can be registered.

In many instances, the requirement of a long flow range can be met by using a bypass arrangement, but this involves electrically operated instruments. The arrangement consists of fitting a small venturi tube on a by-pass from the upstream to the throat of the large venturi tube. The small venturi tube, as well as the main one, works in conjunction with its own instrument; both the instruments are of the conventional U-tube form, but fitted with electrical transmitters. When a flow takes place through the meter and bypass, the head loss through the bypass is equal to the differential head generated by the main venturi tube and, consequently, the differential head generated by the bypass venturi is very much larger than that generated by the main one; the relationship between head loss round the bypass and differential head generated by the bypass venturi is dependent on individual circumstances. At the lower flows, the bypass venturi is utilised for metering purposes, but when the flow exceeds a certain predetermined value, where sufficient differential head is generated by the main venturi, the instrument of this latter tube automatically comes into operation, the other instrument, having now reached its maximum, being cut out of operation. Of course, when the flow exceeds the changeover

value, the instrument of the bypass venturi is overloaded, but due precautions are taken to protect it from damage and it comes into operation again when the rate of flow falls below the changeover value. Both transmitters operate with one receiving instrument which records the variations in flow, in equal-spaced progression, on a rectangular chart. In view of its low head-loss characteristic, the Dall tube is admirably suited for use on bypass.

Weirs and Flumes

As mentioned at the beginning of this article, for a continuous record of the flow through open channels, the weir and the venturi flume are available. The weir meter is so well known that it is hardly necessary to comment on it here, but attention may be drawn to one important factor which is so frequently overlooked. The flow formulae are based on the assumption that certain well defined conditions are obtained on the upstream side of the plate, notably in relation to velocity of approach and side and bottom contractions. If the installation is designed in such a manner that it is not within the four walls of the specification, the danger of unsuspected errors in registration is always present. The recommended types of weirs, and formulae to be used, will be found in B.S.S. Code for Pump Tests, No. 599 : 1939, which also gives proportions for the design of the approach channel. It must be admitted that the upstream requirements listed by the specification have a considerable factor of safety, and in practice these can frequently be modified to suit local conditions with no significant effect on the accuracy of the flow record. However, the permissible degree of modification is a problem that should be settled by a designer who is well versed in such matters.

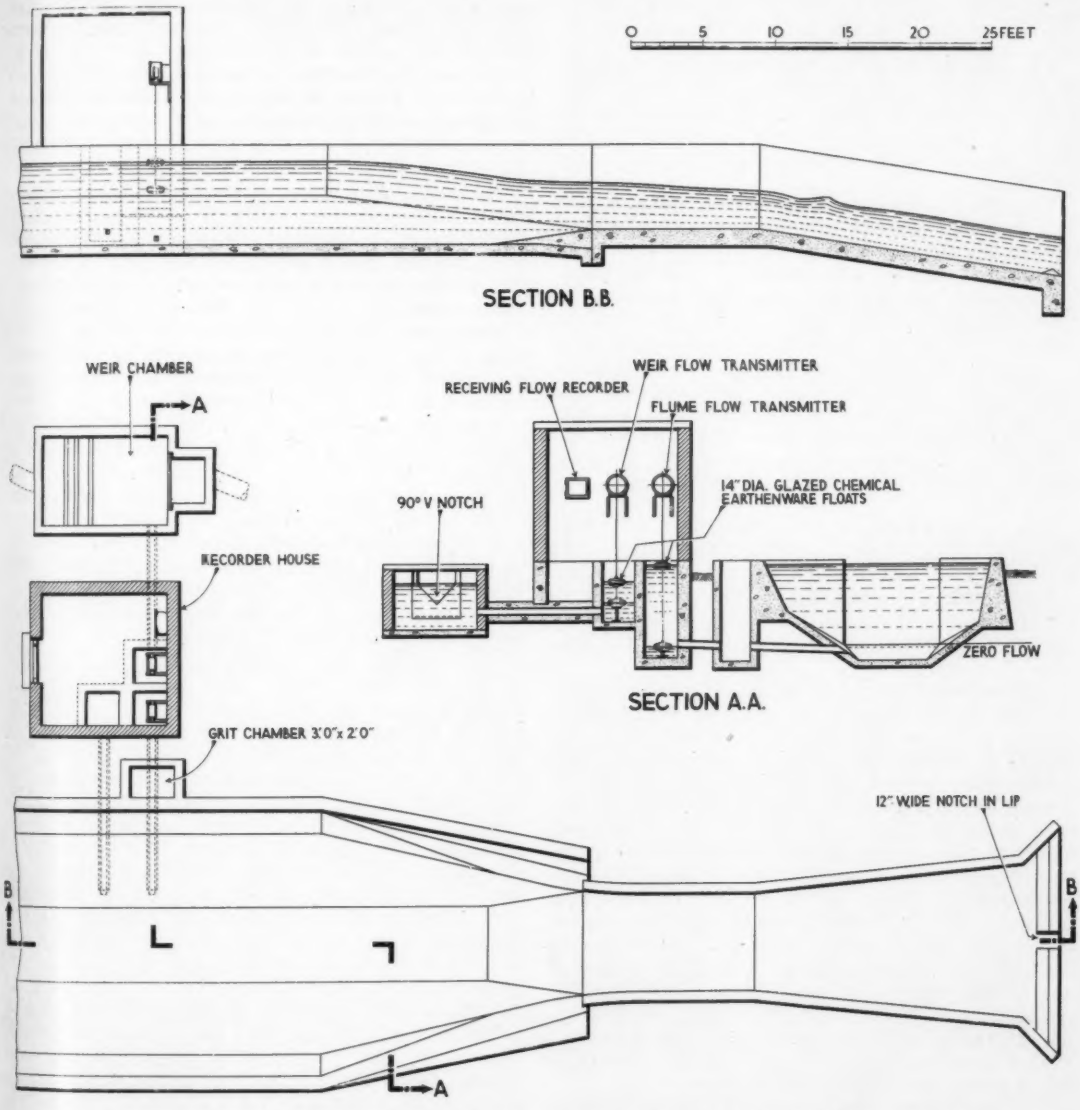


Fig. 6. Trapezoidal flume and weir giving a summated flow on a Kent Multelec recorder

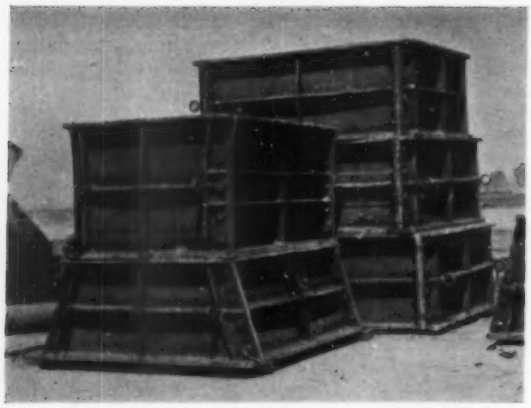


Fig. 7. Kent venturi sections for a London sewage works

The development of the venturi flume was the result of the demand for an open-channel flow meter which would cause the minimum loss of head and not be liable to silting, both of these desirable features being conspicuous by their absence in the case of the weir meter.

The other advantage of the venturi flume is that it is generally possible to construct it in a channel without any serious structural alterations, it only being necessary to form a local contraction, standard building materials, e.g. concrete, being used for this purpose. Sometimes metal plates are provided for the critical throat section. Here it may be mentioned that the venturi flume has been likened to a rectangular venturi tube "with the lid off." The upstream and throat sections need not be rectangular and can conform to the cross-sectional shape of the channel, e.g. trapezoidal or semicircular; in general, the construction of a venturi flume cannot be regarded as a very costly item.

The standard form of venturi flume is of the "free-discharge" type, where a standing wave is formed on the downstream side of the throat. Under this condition, the rate of flow is a function of the depth of flow in the upstream section, and this enables a simple float-operated instrument to be used to register the flow rate.

There appears to be the impression in many quarters that the venturi flume is a measuring device which gives a very low loss in head. Although this contention is correct when the device is compared with a weir, there is no doubt that, if danger of silting is not present and expense is of secondary consideration, by lowering the base of the channel and constructing a venturi tube, a considerably lower head loss would be obtained than is possible with a flume. On the other hand, of course, due to the rate of flow being proportional to the upstream depth raised to a greater power than unity, a very long flow range can be obtained with a venturi flume, and in this respect it has a very definite advantage over the differential-pressure meter. For example, other things being equal, the differential head for one-fifth full flow through a venturi tube is equivalent to approximately one-125th full flow through a venturi flume.

The exact head loss through a venturi flume is dependent on the design, e.g. the "throat" ratio, but as a general rule it may be assumed that this loss is equal to approximately 20 per cent. of the upstream depth. In the design of the venturi flume a reasonably accurate knowledge of the probable head loss is essential because, in order to preserve the free-discharge characteristic over the whole range of the meter, the head loss available must be greater than the minimum that can be tolerated. As a result, when head loss is important, as it nearly always is, the design work involved is considerably more than that for a differential-pressure meter. A full knowledge of the hydraulic conditions downstream of the meter must be known, so that the natural depth/flow characteristic can be ascertained. In addition, full regard must be taken of any possible backing up effects which may result from artificial or natural causes. In the instance of relatively steep channel slopes, attention must be paid to the possibility of the formation of standing waves, or at least disturbed conditions, in the upstream section. Means for regulating the flow through a venturi flume need careful design. Control on the downstream side is impossible, since it will result in drowning, and therefore such control must be located upstream of the meter—contrary to standard practice for differential-pressure meters; unless steps are taken to smooth out disturbance due to this cause, inaccurate registration is inevitable.

It is sometimes found that, in designing a venturi flume, it is under free discharge conditions over the higher range, but drowned at low flows. To avoid excessive head loss at the higher rates of flow, instead of reducing the throat width so as to increase the upstream depth to obtain free flow at low flow rates, a hump may be incorporated at the throat, or the base of the flume may be raised over the upstream and throat sections. By adopting this design, the resultant extra head loss is much reduced.

Attention may be drawn to the use of compound venturi flumes when an extremely long flow range is required. The general principle of construction is to divide the channel into three sections with longitudinal walls having the appropriate contour. The centre section has a flat invert while the outer two are constructed with humps. It follows that at the low rates of flow all the water passes through the centre section, the outer sections coming into operation when a predetermined rate of flow is exceeded.

The question that naturally arises is why not use a drowned venturi flume. That is to say, a venturi flume in which the flow is proportional to the difference in level between the upstream and throat sections, there being no standing wave formation. In theory, there is no objection to such a design—in fact, meters of this form have been made and are in operation—but there are certain serious objections. The instrument required becomes very complicated, it being necessary to multiply automatically the square root of the difference in level between the upstream and throat by the throat depth. In addition, quite a moderate degree of drowning reduces the difference in level between the upstream and throat to a considerable degree, and practical difficulties are involved in automatically extracting the square root of a small value and multiplying it by a value that is very much greater. In consequence, when designing a drowned venturi flume it is necessary to ascertain the degree of drowning, which calls for a knowledge of existing

(Continued on page 149)

Constant-Current A.C. Transmission

Percy H. Thomas, of Montclair, New Jersey, contributes a memorandum on the potentialities of constant-current a.c. transmission in the light of the editorial article "Energy Transportation" published in our January issue.

THE present memorandum is intended to outline some of the advantages and potentialities of constant-current (c.c.) transmission in a normal constant-potential electric power system. Such a system envisages a constant-potential (c.p.) normal generating layout, normal c.c.—c.p. wheatstone's bridge network, normal step-up transformers, c.c. transmission, normal step-down transformers, a second c.c.—c.p. network, and a normal c.p. receiving system. The salient characteristics are here summarised:

Stability. When a heavy overload or partial short occurs on the receiving circuit, the nature of the c.c.—c.p. network is such that the heavy current in the c.p. circuit causes a heavy voltage rise in the c.c. circuit, and the lowered voltage in the c.p. circuit causes a current reduction in the c.c. circuit, the result being a great strengthening of the delivery power of the line. Further the low power factor of the c.p. circuit of the system becomes a low leading power factor in the c.c. system. This still further strengthens the transmission. This may go to a momentary delivery of two or three times the power deliverable from the normal c.p. transmission.

Again, if each of several transmission lines has its own c.c.—c.p. networks, as would be natural in a large system, a short on one line does not become a drag on the others, as the voltage drops on the bad line without changing the current. This is a far-reaching feature.

Power factor. The fact just stated that the lagging power factor of the c.p. circuit becomes leading in the c.c. circuit requires an entirely new view of the power-factor balance. The reactive leading energy in the c.c. portion of the receiving circuit passes through the step-down transformers where it is reduced in magnitude by the reactive energy developed in the transformers. The balance of leading energy in the receiving end of the line is then gradually reduced by the reactive lagging energy from the line itself, and, in a favourable design, might approach unity at the sending end. Then the lagging reactive energy in the step-up transformers would give a slightly lagging load in the generators. This greatly reduces the synchronous-condenser requirements.

Another important factor comes in here; the economical load on a normal c.p. line is limited by the heavy reactive energy developed by the line current in the line. With the presence of surplus leading reactive energy in the line from the lag of the c.p. receiving circuit larger transmission loads should be feasible. Perhaps the high-tension circuit with divided conductors in each phase, proposed by me before the A.I.E.E. in 1909 might give a favourable flexibility in adjusting the voltages and numbers of circuits, etc., for the optimum balance. The net effect of these new combinations in an actual system requires long study, only the suggestion is here made.

Duty of Line Circuit Breakers. Since the normal functioning of the c.c.—c.p. network requires the proper frequency and the proportioning of the inductances and condensers to the operating conditions as to current and voltage magnitudes, any radical departure voids the co-operation between these elements, and the network lies as a bar in the circuit. This means that no short or ground on the line can cause a heavy rush of kVA and put a load on the circuit breakers. A plain metallic short merely produces normal c.c. with a very low voltage on its supply circuit. With each line with its own network, trouble on one line does not interfere with the duty of circuit breakers on another.

Line Losses. With c.c. in the line the line losses are constant regardless of load, but this difficulty is not as troublesome as appears at first sight.

In large-capacity long-distance transmission the load factor and capacity factor are usually high so that the question of light load losses is not too important.

In case of light load in such a transmission, one or more lines may be cut out for the duration of the light load.

With two independent lines, it is possible to use one to change the transformer ratio without shutting down so that the line current may be proportionally reduced.

In the case of cutting out lines for light load, the lines may be automatically cut in again as the load comes back.

The conductor losses, the corona loss, the core losses and the synchronous-condenser losses at the receiving end are all interrelated, and the most economical conductor size, voltage and synchronous-condenser layout may be definitely different in a c.c. layout from a c.p. As to which will be the more favourable requires study of each case.

Safeties and controls furnish a large field for exploration, but this is not the place.

Full-Scale Try-out. A full-sized try-out of a line of the type here under discussion may be had relatively easily and cheaply by selecting a long-distance line circuit from one of the known large-capacity installations now in existence, and isolating it with appropriate generators. With an appropriate c.c.—c.p. network at each end this line could pump power through the line to the c.p. receiving network, with which it would work in parallel. Then in case of trouble on the c.p. receiving circuit this line would supply its extra-competent support to the receiving circuit as described above. After the first momentary support it would continue to support it presumably to the ability of the generators connected to that line circuit.

Apparently the experience with large-capacity condensers has arrived at a point where they can be used with confidence.

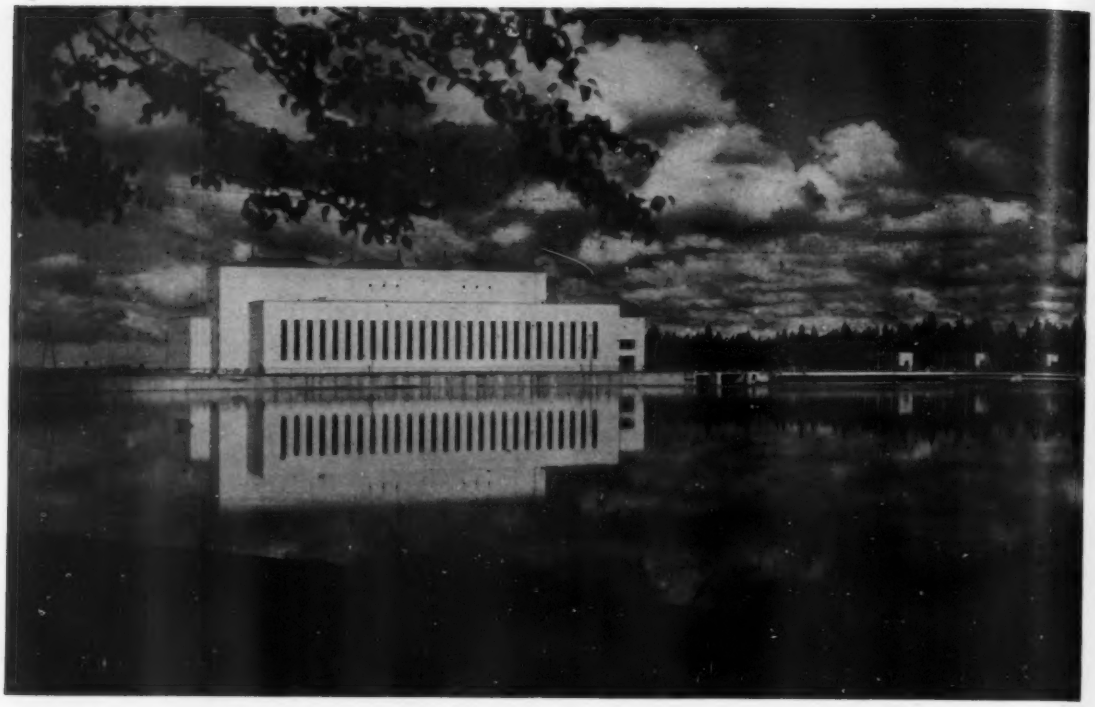


Fig. 1. A general view of Pyhäkoski station looking downstream

Hydro-Electric Developments in Finland

By V. Veijola, Electrical Inspectorate, Helsinki

FINLAND is known abroad as a country of lakes and forests and certainly it is these two basic features which determine, in great measure, the possibility of its four million inhabitants to embark on industrial activity and foreign trade, thus raising the standard of living and the general welfare of the people. The rivers flowing into the sea from the 60,000 odd lakes of the country give the industry its main motive power, and from the forests we get the raw material of our most important export industry, the timber industry.

The vast number of lakes might give anyone not very familiar with the circumstances the impression that nearly unlimited water power resources were available. Unfortunately, the following survey will show that this is not the case.

The present area of Finland, excluding those territories ceded to the U.S.S.R. at the armistice, covers some 337,000 km², and the total area of the lakes is about 32,000 km², i.e., nearly 10 per cent. of the total area of the country. The annual mean value of the rainfall in the country is about 550 mm. The run off, which, of course, is the determinative for the water power purposes, achieves a mean annual value of about 3,000 m³/s. If mere quantity of flowing water were the only criterion it would be possible for Finland to possess power resources of almost immeasurable magnitude, but the main negative factor in this respect is the lowness of the country. In Fig. 3 is shown an approximate topographical sketch of Finland with contour lines spaced at intervals of 50 m. The major portion of the lakes is located in the territory between the 50 m. and 100 m. contours so that the average height above sea level is about 75 m. From this it follows that heads of 5 to 8 m. are usual, a head of 15 m. being considered as high, and a head of about 32 m. is the highest that potentially exists. When estimating the theoretical total amount of the water power resources in such a way that the average height of every square kilometre is multiplied by that amount of water which flows during a year from this area into the sea, we come to an average result of 30 milliard kWh a year. This theoretical figure is not, of course, in its entirety the amount of energy which is technically available for harnessing. If we regard 2 m. as being the limiting head for practical purposes, and an average flow of at least 5 m³/s., we get a figure of approximately 15 milliard kWh a year.

In assessing Finland's water power resources it is

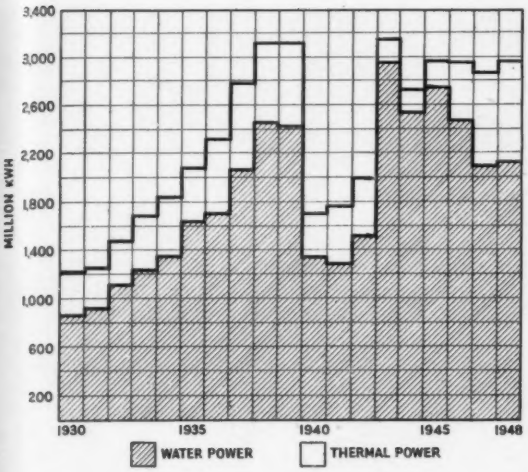


Fig. 2. Annual total production of electrical energy in Finland during the period 1930 to 1948

convenient to distinguish two regions which differ very much from each other: first, those resources located in the South and Middle Finland amounting to 40 per cent. of the total, and second the remaining 60 per cent. which includes the Oulujoki water system, located in the North. Due to the equalising effect exerted by the large lake area in South and Middle Finland, the seasonal variation in the river discharge is very slight. On the other hand, the annual total amount of water may vary to a great degree, e.g., in one of the main rivers of the area,

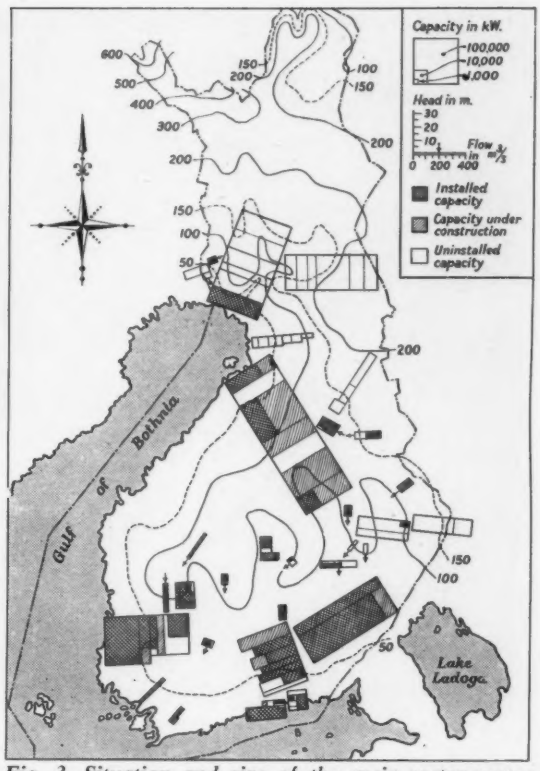


Fig. 3. Situation and size of the main water-power resources of Finland. showing also the main contours at intervals of 50 m.

Fig. 4. An aerial view of the 23,000 kW Ahvenkoski power station on the river Kymijoki in South Finland

Fig. 5. Kolsi power station on the river Kokemäenjoki, having a rated capacity of 21,700 kW

in the river Kokemäenjoki, there may be nearly four-fold variation. This phenomenon arises from the great variations in the climatic conditions from year to year, the quantity of water evaporated having a profound effect on the run off and hence on the potentialities of power production. It is not possible to eliminate this drawback even by means of the most far-reaching conservation measure as the shores of the lakes, which are thousands of kilometres long and densely populated, prohibit any possibility of raising the water level to any effective extent. As a characteristic example, one of the main lakes, Saimaa, from which, among others, the Imatra station, the largest in Finland, gets its water, may be mentioned. The total length of the low shores of Lake Saimaa are no less than 14,000 km. and allow a height regulation of 1·25 m. only. On the other hand, the lake troughs cannot be lowered appreciably without endangering the facilities for floating timber, which are of vital importance to the woodworking industry. On this account in order to be able to utilise rationally the water power resources in the South and Middle of Finland, it has been necessary to provide fairly extensive systems of thermal power, to enable industrial production to be maintained during the periods of water shortage.

In the north the situation is different. Here, because of the short summer and the cool climate, the annual evaporation is so small that the variations in run off are appreciably less and in the main drainage system in the area, connected with the river Kemijoki, are less than twofold. On the contrary, the seasonal variations have a considerable range owing to the lack of lakes. For example, the lowest measured flow is about 90 m³/s., whereas the highest is about 4,100 m³/s., with an average value of 530 m³/s., amounting to a 45-fold variation. However, this drawback will be eliminated to a considerable extent by creating large artificial lakes in the sparsely settled and uninhabited districts and using these impounded in times of drought.

Prewar Development

The utilisation of water power for the generating of electrical energy started in this country rather more than half a century ago. Development was naturally very slow in the early days, as the economic justification for intensive expansion did not exist. This was partly because of the out-of-the-way location of the country, which was held as a Grand Principality of Russia at that time. So it was that the total amount of the electrical energy generated remained under 100 million kWh per annum until 1918. When Finland had become an independent republic in 1917, the foundation was laid for a much freer economic development, and although the effects of the 1914-18 war retarded progress during the 20's, the next decade, up to the period of the 1939 war, was one of notable expansion. Even by 1925 some 500 million kWh a year had been achieved and in 1929 the 1,000 million kWh mark was passed. Important construction works of power stations in the three main rivers of South Finland: Vuoksi, Kymijoki and Kokenmäenjoki were started in the 20's, the most important being the first stage of the Imatra power station which was completed in 1929, and which even now is the biggest power station in Finland. The first stage involved 4 units of 24,000 kVa each designed for a flow of 100 m³/s. at a head of 24 m. This station was later enlarged on several occasions and in the near future, when the 7th unit has been put into operation will have a total capacity

of 150,000 kW capable of dealing with an average flow of 765 m³/s. and producing some 1,000 million kWh per annum. Concerning other important water power stations put into operation in the 30's mention may be made of Rouhiala and Harjavalta stations, the former also situated on the river Vuoksi (it was ceded to the U.S.S.R. at the armistice). It had a capacity of 97,000 kW and an annual generation of 630 million kWh. The Harjavalta station situated on the river Kokemäenjoki, has a capacity of 73,500 kW and operates on a head of 26.5 m. generating 389 million kWh per annum with an average flow of 220 m³/s. Thanks to lively constructional activity, an output of 3,112 million kWh was achieved in 1939, of which 2,435 million kWh were generated by water power. At that time the installed hydro-electric capacity amounted to 512,000 kW.

Fig. 6. The Imatra rapids before harnessing. Photograph taken from a painting of 1890

Fig. 7. The same view after harnessing. The regulation dam of the Imatra power station is seen in the background

The postwar development and some aspects for the future

The second world war and the treaty which followed it gave the power economy of Finland a serious set-back. In accordance with the treaty we were obliged to give up a total installed capacity of about 171,000 kW, the share of the water power being approximately 121,000 kW, representing 17 per cent. of the total capacity of the country and 24 per cent. of the installed water-power capacity. Taking into account the schemes under construction and potentially available Finland was deprived of approximately 316,000 kW capacity and a production of 2,500 million kWh per annum—about 17 per cent. of the total resources. In addition to this, during the few years following the war an acute water shortage was experienced and the country was faced with a very severe shortage of electricity, the winter of 1947-1948 being exceptionally severe.

During the war but more especially after it large-scale projects were put in hand to replace the lost generating capacity. These schemes involve eleven new hydro-electric stations with a total capacity of about 390,000 kW and a total output of about 2,145 million kWh per annum. Up to the present some 168,000 kW of new capacity has been put into operation, generating 1,210 million kWh per annum and it is hoped that this entire plan will have been completed by 1952. The most important project in this development scheme is the harnessing of the river Oulujoki, situated in the middle part of Finland. This will involve the erection of three power stations having a total capacity of 186,000 kW and an output of 980 million kWh per annum. The biggest of these stations is the Pyhäkoski station, Fig. 1, rated 108,000 kW and an annual production of 560 million kWh, with an average flow of 400 m³/s. and a head of 32 m. The very first 36,000 kW unit of this plant was put into operation in the spring of 1949. The energy generated at this station will be transmitted to southern Finland by means of the first 220 kV overhead power line in the country, which will be some 500 km. in length.

Fig. 3 gives a diagrammatic representation of the whole Oulujoki development area, involving seven plants with the total capacity of 397,000 kW and an aggregate output

Fig. 8. 220 kV power line from Pyhäkoski to Hikiä in course of erection

Fig. 9. Staff dwellings for personnel at the Pyhäkoski power station

of 2,083 million kWh per annum. Besides the three stations at present under construction it is anticipated that two additional plants will be completed by 1954, thus making a total of five completed within the confines of the Oulujoki river.

With the other projects in course of construction this will mean that electrical generation will have been more than doubled within ten years. The total installed capacity of water power plants which remained to Finland at the time of the armistice amounted to 415,000 kW, producing 2,500 million kWh per annum; in 1954 the corresponding figures will be 950,000 kW and 5,400 million kWh respectively.

Both in regard to existing and projected plants the installed water power system of ownership is various, some belonging to the state, some—particularly industrial plants—to private companies and some to municipal authorities, but state ownership is most common. The administration of the state-owned stations is vested in limited companies, in which the state, however, holds absolute share majority. Close collaboration is maintained between these three owner bodies and practically all the power stations in the country run in parallel, the large-scale exchange of power taking place continuously.

By 1954 practically all the water power resources in the south and middle Finland will have been harnessed, and measures will then be taken to develop the resources of the North, giving particular attention to the potentialities of the Kemijoki. The most important problem in connection with this development will be to plan the necessary artificial storage lakes, to equalise the flow and to minimise the detrimental effects of the great variations in the seasonal run off.

When estimating the anticipated use of electrical energy on an annual increment basis experience shows the annual rate of increase to be 7 per cent., we arrive at 6,200 million kWh for the required output of 1955, and 16,000 million kWh for 1970. Our water power resources would have been exhausted within that time, and further increase would have been met by means of thermal or wind power, unless no other more advantageous energy source had been developed in the course of the years.

Fraser River Model

A movable-bed hydraulic model of the Fraser river estuary has been constructed on the campus of the University of British Columbia to study maintenance and improvement problems in the navigation channels. The model, which incorporates all the channels below New Westminster in movable-bed form, and the channels from New Westminster to Sumas, including Pitt river and Pitt lake, in fixed-bed form, is to a horizontal scale of 1 : 600 and a vertical scale of 1 : 70. A large section of the Gulf of Georgia is included to aid in the accurate reproduction of tides. Automatic controls, which vary the discharge of the river and control the height of the tides in accordance with prototype data over a one-year period, have been incorporated.

The model has been in operation since early in the year. Minor modifications have been made to the controls to improve their efficiency and reliability and they will now operate without attention for the equivalent of one prototype year which is the normal length of test period.

Tests have shown that the channels were somewhat too smooth and the range of water levels in the river caused by the influence of the tides was considerably too great. By placing a number of screens across the channels to increase the roughness, it was possible to obtain close agreement between the model and prototype gauges for all conditions of tide and river discharge.

Natural river sand of 0·350 mm. median grain diameter was used to mould the movable-bed channels. No bed movement was visible in any part of the model. The use of 0·290 median diameter sand in a few strategic areas showed a slight improvement. A finer sand, 0·180 median diameter, showed definite improvement and it is probable that this material will be used throughout the movable-bed portion of the model, depending upon the results of further tests.

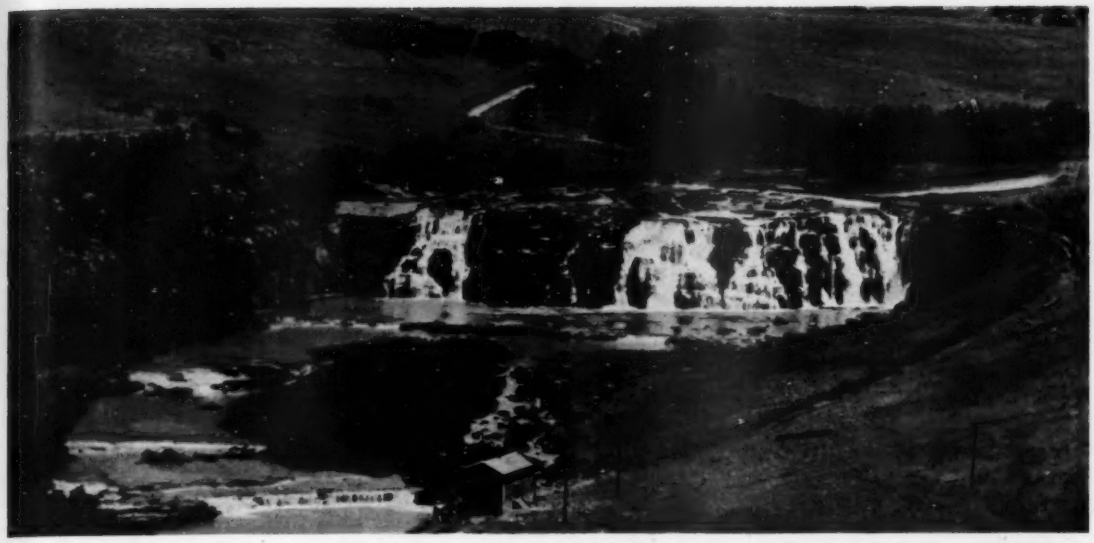


Fig. 1. View of the Umtata Falls

Remote-controlled Hydro-Electric Plant for South Africa

A brief account of a G.E.C. 200 kVA remote-controlled Francis turbine set at Umtata Falls, Cape Province.

UMTATA is a town of growing importance in Cape Province, the Union of South Afrcia, and is the Administration Centre for the native reserve known as the Transkei. It may be mentioned that a native reserve is an area in which no European is allowed to own ground freehold, but can only hold it on lease by permission of the Union Government. The town, which is approximately 2,300 ft. above sea level, is fortunate in its location on the Umtata river which is one of the few rivers in Africa which remains in flow during the dry season, usually extending from May to August.

Four miles from Umtata are the Umtata Falls, Fig. 1, which have served the town as a source of power since twenty years ago. At that time a small dam was constructed above the falls and a 100 kW hydro-generating set was installed in a power station erected a little way downstream from the falls. In the last few years, however, the town has been growing considerably and it was decided that a greater output was greatly to be desired. As a result of this decision a new pipeline was laid and an additional 150 kW water turbine alternator has recently been installed by The General Electric Co. Ltd. of England.

The power station is situated in such a position that it can only be approached on foot, and this over very hilly and difficult ground—that is, difficult for a European, for the native women traverse the distance to it with apparent ease notwithstanding that they carry five-gallon drums of water balanced on their heads. Locusts and hornets abound in this area. The hornets are somewhat troublesome as they have the unfortunate habit of choosing inaccessible parts of the electrical gear as suitable spots in which to build their mud nests.

Owing to its inaccessible location, the power station is unattended and the new plant is fully automatic, being controlled over pilot wires by two push-buttons in the Town power station. The new pipeline, 1,000 ft. long and 30 in. diameter, was laid to enable the new turbine-generating set to operate from a pressure head of 91 ft. and a suction head of 17 ft. The set consists of a 225 h.p. 750 r.p.m. Francis turbine with flywheel and governor, directly coupled to the alternator which gives an output of 200 kVA at 400/230 V, 3-phase, 50 cycles. The output voltage is stepped up to 3·3 kV by a 200 kVA transformer for overhead transmission to the Town power station. Each of the two sets in the Falls power station supplies energy over its own transmission lines, but synchronising gear is provided at the Town station so that, when necessary, the total output of the hydro-station may be transmitted over either set of lines.

The remote control system, which is shown

diagrammatically in Fig. 2, is energised from a 380/220 V, 3-phase, 4-wire supply at the Town station. Complete control of the generator is effected by means of two pushbuttons, one for starting and speeding up and the other for stopping and slowing down. These pushbuttons energise the overhead pilot control wires at either 220 V or 380 V a.c. respectively and the appropriate voltage is supplied to a metal rectifier in the control cubicle at the Falls station. This rectifier feeds a voltage selector relay through which the appropriate contacts are operated.

When the "start" button is depressed, the voltage selector relay completes a supply to an interposing relay which closes the main field contactor and, at the same time, energises a contactor panel controlling the sluice valve which begins to open. This valve is motor operated and draws its supply from a 24 V battery in the basement of the Falls station.

As the sluice valve opens, the set picks up speed until, finally, the governor takes over control and brings the machine up to full speed. Since the main field contactor closes at the beginning of the operation, the output voltage builds up as the speed increases until, at a predetermined value, a relay connected between one phase and neutral of the machine operates to close the main oil circuit breaker which connects the alternator to the transmission line.

Once the sluice valve is fully open, a limit switch disconnects its driving motor and also completes a circuit which enables the "start" button to be used for raising the speed of the machine via the governor gear for purposes of synchronising and load control. In addition, the "stop" button can now be used for lowering the speed of the machine down to the lower limit of governor control.

In order to shut down the plant, the "stop" button is depressed and held in this position until the speed has dropped to the lower limit of governor control. At this point, a change-over limit switch operates, disconnecting the governor control circuit and simultaneously energising the "close" contactor for the sluice valve motor. As the sluice valve starts to close, its "open" limit switch resets, thus opening the circuit to the interposing relay which then completes the trip circuit for the oil circuit breaker and the main field switch. The sluice valve motor continues to run until the valve is fully closed at which stage the alternator is completely shut down.

The plant is fully protected against excessive bearing temperature, overspeed, governor failure, and internal faults of the alternator and transformer. Any of these faults will operate a lock-out relay which trips the oil circuit breaker and field contactor, thus shutting down the set which cannot be restarted until the fault is cleared and the lock-out relay reset. The equipment is also provided with over-current and line fault protection devices which will disconnect the machine from the busbars but will leave the set running. By depressing the "start" button, the switches connecting the machine to the busbars will close again and, if the fault is clear, will remain closed. If the fault is still present, however, these switches will again open, simultaneously operating the lock-out relay which will then shut down the set. Whenever the lock-out relay operates, it is necessary to visit the Falls station in order to reset this relay before the generating plant can be restarted. In the case of overvoltage, or excessive alternator or transformer temperatures, the machine is disconnected and shut down but, since the relay resets automatically when conditions have returned to normal, the set can be restarted without its being necessary to visit the station.

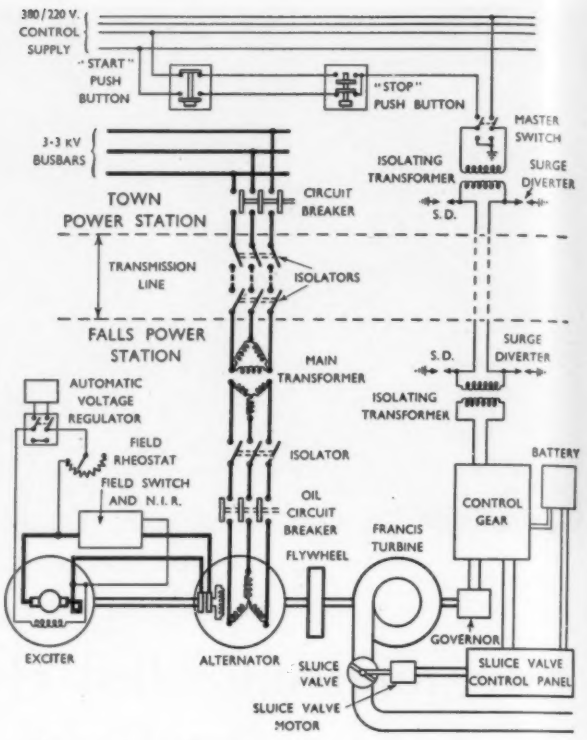


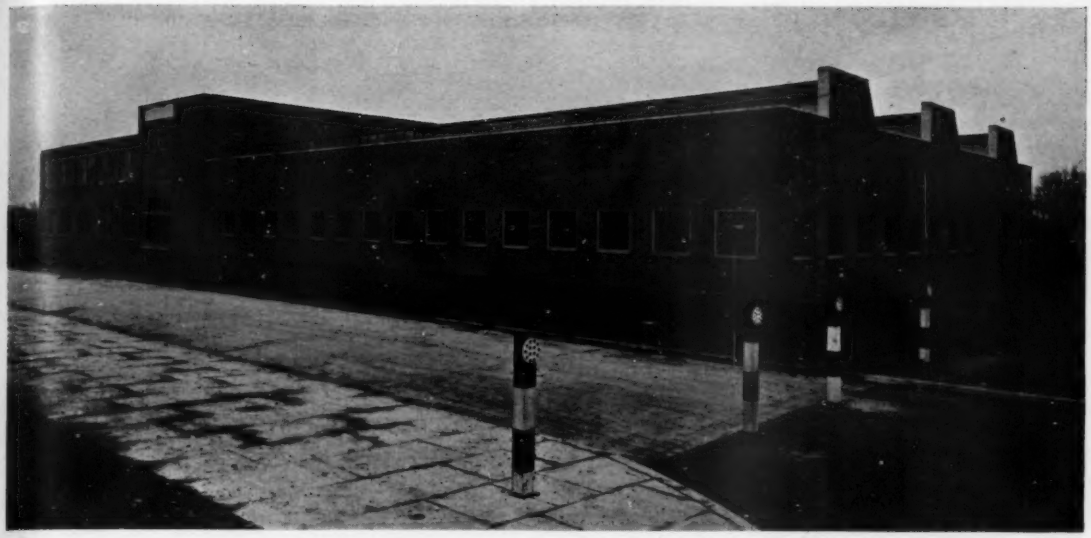
Fig. 2. Circuit diagram of the remote-control system

In view of the frequent occurrence of electrical storms during the rainy season, provision is made for the protection of the pilot control wires against lightning surges, a one-to-one isolating transformer together with the necessary surge diverters being provided at each end of the line.

During the dry season, the river flow drops to about 8 million gallons per day, but the governor is fitted with a low-water flow regulator whereby the output is correspondingly limited.

Loch Sloy Power Scheme. A booklet describing this well-known Scottish scheme has been produced by The English Electric Co. Ltd. The publication, which runs to 20 pages within covers, is a reprint of the article published in the June 1951 issue of *The English Electric Journal*, and covers civil, mechanical and electrical engineering aspects.

Constructional Equipment Film. A film sponsored by Frederick Parker Limited, of Leicester, shows a wide range of this firm's plant used for civil engineering contracting work. Of particular interest to hydro-electric engineers are the shots of the Erne scheme in Ireland and the large Castelo do Bode scheme in Portugal.



The British Hydromechanics Research Association

We give a summary of the formation, scope and activities of this Association, which was set up four years ago by a group of British manufacturers of hydraulic machinery and last year acquired its own laboratory at Harlow

SINCE the war hydraulic research in Great Britain has expanded greatly. The relatively small amount of work carried out in the former Engineering Division of the National Physical Laboratory has now been expanded into two much larger groups: the Hydraulics Research Organisation which has its laboratory at Wallingford to study open channel and loose-boundary problems, and the Fluid Mechanics Division of the Mechanical Engineering Research Organisation whose laboratory at East Kilbride near Glasgow will deal with the mechanical engineering side of fluid flow.

It has ever been the genius of British industry to parallel government research by research undertaken by manufacturers. There is no element of opposition in such a procedure, for government research tends to a study of long-term fundamental problems, whereas manufacturers' research is concerned much more with *ad hoc* investigations. Good liaison is normally maintained between the two organisations, and, indeed, research on the part of industry is usually aided by government grants.

Similar ideas have prevailed for some time amongst the manufacturers of hydraulic machinery and plant, and four years ago a group of these manufacturers formed the British Hydromechanics Research Association to carry out research on their behalf. Since then the membership has grown to include most of the British manufacturers of pumps, turbines and other hydraulic machinery, users of hydraulic equipment, consulting engineers, and research workers.

The field to be covered by the Association is a wide one, and six sectional committees have been set up to deal with fundamental fluid mechanics, measurement and laboratory technique, centrifugal and allied pumps and turbines, control and motion of fluids in pipes and valves, seals and joints, and reciprocating machinery and displacement pumps and motors.

A grant is received from the Department of Scientific and Industrial Research, and contact is maintained with the establishment at East Kilbride, both by visits of staff and by reciprocal membership of committees. There is also liaison with hydraulic research workers at universities.

An important step forward was taken last year when the Association's laboratory was completed and officially opened by the President, Lord Waverley, then Sir John Anderson, supported by the President of the Institution of Mechanical Engineers, Mr. A. C. Hartley, and the Chairman of the Association, Mr. G. A. Wauchope (recently succeeded by Dr. A. Ivanoff). The laboratory was the first industrial building

Fig. 1. Test tank containing model of the Weir Wood spillway

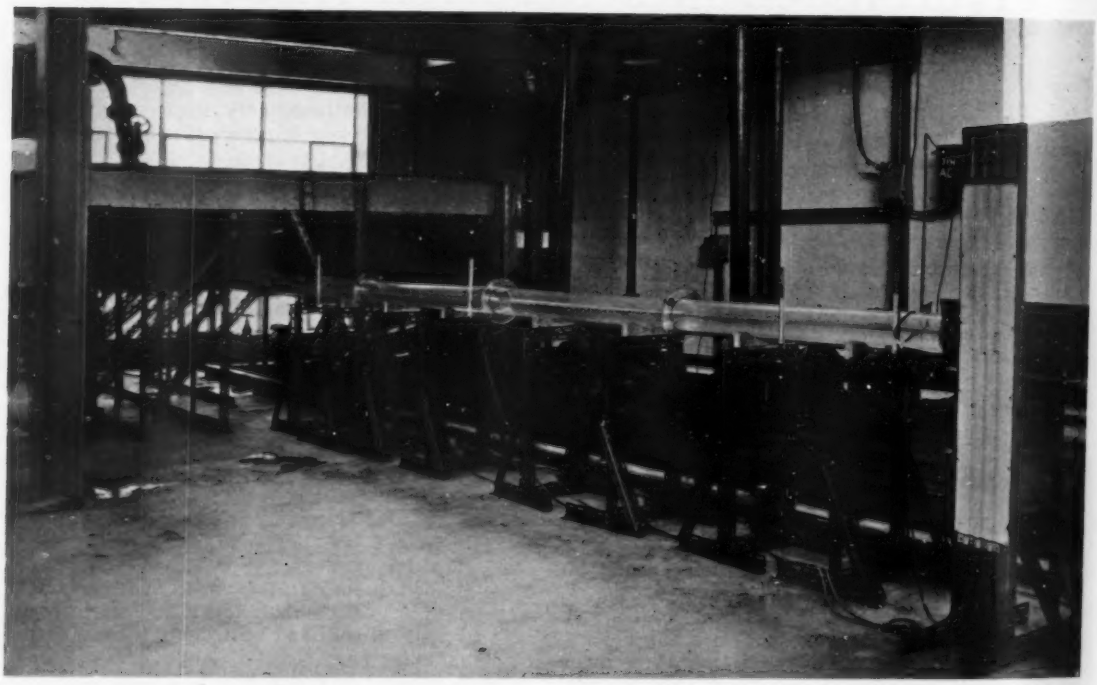


Fig. 2. The Perspex model of the discharge tunnel from the spillway illustrated in Fig. 1

to be completed in the new satellite town of Harlow, near London, and is a building, 120 by 72 ft., single-storey except at one end, where a gallery gives additional height for pump suctions, etc. A sump and various tanks are installed, but the layout has deliberately been kept as open as possible to facilitate temporary rigs. A machine room, generator room and oil laboratory are provided. A two-storey office block adjoins the laboratory, and includes a library, drawing office, dark room and instrument laboratory.

One of the most interesting investigations that we saw in progress during a recent visit to the labora-

tory was one on the overflow spillway and outlet tunnel for a reservoir being constructed by the Weir Wood Water Board for the new town of Crawley. This work is being carried out on behalf of the consulting engineers, Herbert Lapworth Partners, for whom a second model investigation is being carried out to study a different design of spillway and outlet tunnel for a scheme projected by the Yeovil Rural District Council.

In the original design for the Weir Wood scheme the spillway is circular and forms the lip of a bellmouth which leads through a mitred elbow to a concrete-lined tunnel 10 ft. in diameter and about 500 ft. long. The dam is of the earth-fill type and it is therefore important to ensure that the system shall have sufficient reserve capacity to handle a catastrophic flood. The purpose of the investigation is to determine the relationship between head and discharge over the weir, when it is freely discharging, and to determine the maximum discharge of the overflow system. The latter is determined by the resistance of the outlet works and is the discharge at which the weir is drowned.

A one-twentieth-scale model has been constructed, and comprises a tank about 12 ft. square representing part of the reservoir and embankment and containing the spillway (Fig. 1), which leads to a horizontal pipe representing the tunnel. Both the lower part of the spillway chamber and the horizontal pipe have been made in Perspex so that the air entrainment and the flow of the water can be observed (Fig. 2). Already an increase of 18 per cent. in maximum discharge capacity has been achieved by replacing the mitred elbow by a circular-section bend, but this change has led to difficulty in getting the tunnel to run full. Experiments are in progress to overcome this by introducing a hydraulic jump in the tunnel or by modifying the bend.

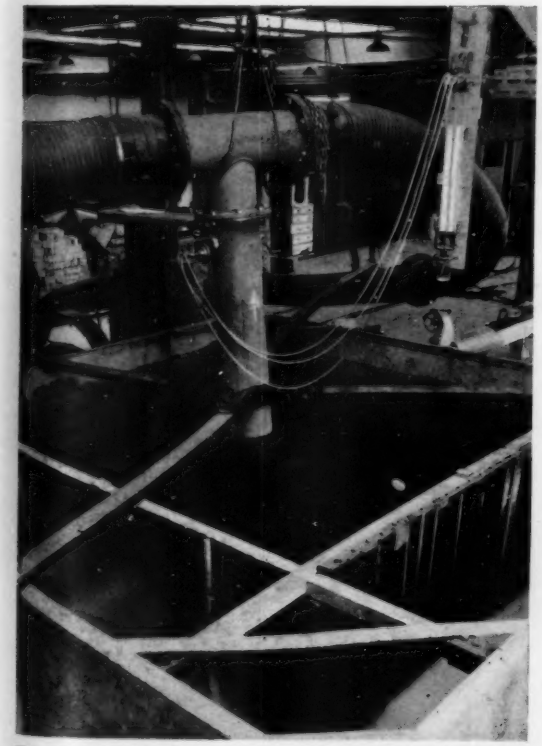


Fig. 3. Movable pump suction for studying formation of vortices in a sump

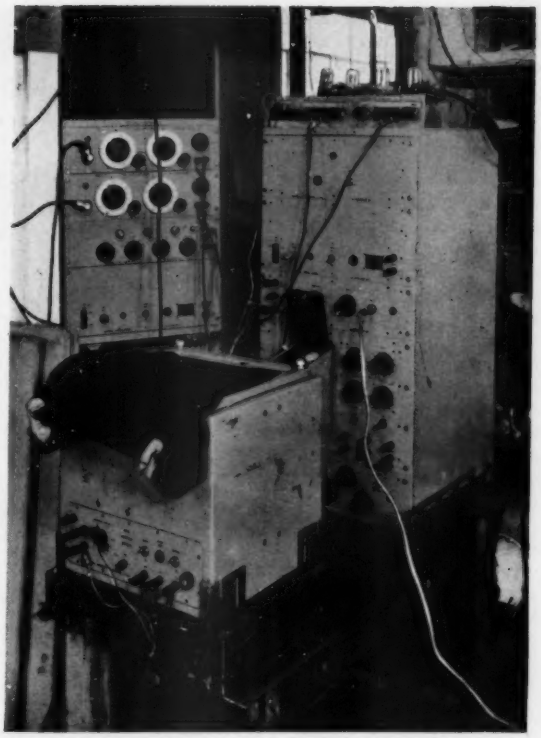


Fig. 4. Electronic recorder in use for studying surges in pipelines

The actual spillway will support a footbridge leading across the bellmouth to the valve tower controlling the draw-off, and in the model the supporting piers were represented by paraffin-wax blocks cut to the correct profile. These piers were solid and involved the loss of about 10 per cent. of the effective circumference of the spillway, and experiments have shown that this loss can be reduced to 5 per cent. by replacing the solid piers by pairs of narrow streamlined struts, as shown in Fig. 1. These streamlined struts also improve conditions in the bellmouth, particularly when the weir is drowned.

A second investigation in progress is on the entrainment of air in a pump suction by vortex formation. This is a practical question because it influences the design of the sump, which may be expensive to construct. A 10 ft. square suction sump has been constructed, as seen in Fig. 3, and suction pipes up to 8 in. diameter can be moved to any position in the tank by the use of flexible hose coupled to the pump suction. The water level in the tank can be varied over a range of 5 ft. Preliminary trials have indicated that air entrainment is influenced more by the flow pattern set up by the entry conditions than by the size or submergence of the bellmouth. With the suction pipe in the centre of the tank, air has sometimes been drawn when the bellmouth was 3 ft. below the surface. On the other hand, when the pipe is placed near to one side of the tank, the proximity of the side may largely inhibit the swirl, showing

that the shape and arrangement of the sump may be determining factors.

An important investigation is in progress on surges in pipelines. A technical note has been issued on the fundamentals of surge transmission, and a further publication is in preparation dealing with the graphical prediction of surge pressures in hydraulic systems. It is stated that there are many systems in which the maximum surge pressures are far higher than is covered by conventional factors of safety. Actual investigations are being conducted with the aid of a high-speed two-channel electronic recorder using electrical capacity-type pressure heads which can be screwed into tapped holes at any desired points in the system. Experimental work has been carried out on the pressure surges caused by starting up a pump with an empty delivery pipe and a practically shut valve some distance from the pump. The pressure surge is generated when the water column strikes the valve disc. The experiments have been done to verify calculations on the best opening to have for the valve for minimum surge pressures. Pressure surges in armoured flexible hoses are complicated by the surge velocity increasing greatly with pressure. Experiments in the laboratory and site

Fig. 5. Test rig for studying the effect of pulsations on the accuracy of meters

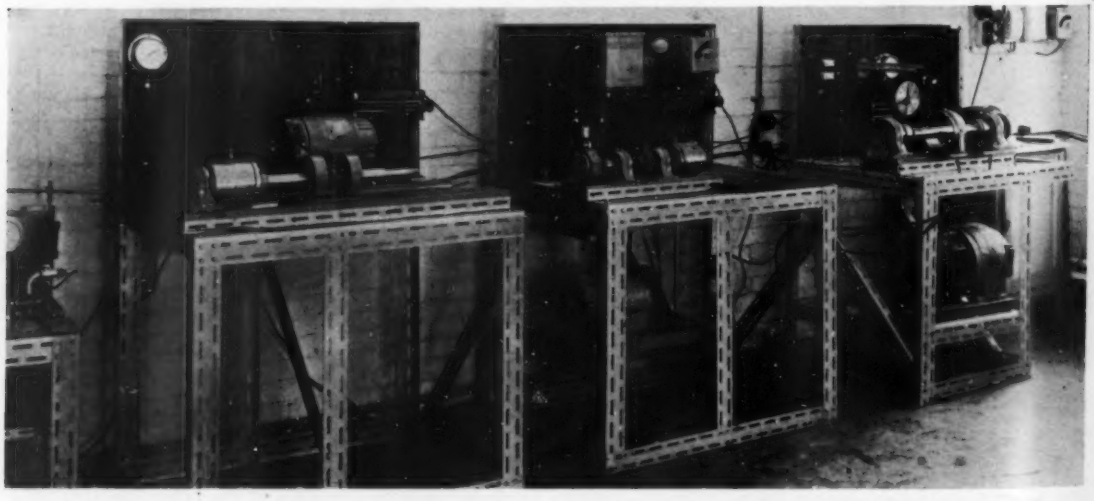


Fig. 6. Equipment for investigating the behaviour of seals, glands and packings

tests on 6 in. high-pressure hoses have shown that the surge velocity increases until the pressure reaches about 150 lb. per sq. in., above which the hose appears to behave as if it were a rigid pipe.

The effect of flow pulsations on the accuracy of commercial meters is being studied with the aid of the equipment depicted in Fig. 5. A steady flow is maintained in a long pipe by the discharge over a weir into an elevated tank, the rate of flow being adjusted by raising or lowering a swinging discharge pipe so that the net head on the system can be varied. At the mid-point of the system a reciprocating plunger imposes an oscillation on the flow, the amplitude and frequency of the oscillation being adjusted by varying the stroke and speed of the plunger. The orifice or venturi, the true discharge coefficient of which is to be determined, is placed at some distance on the downstream side of the plunger. Considerable changes in the manometer reading are found when the character of the manometer or of its pressure leads is changed.

Experimental rigs have been assembled to study the behaviour of stuffing-box packings, lip seals and radial-face seals when used with rotating shafts at speeds up to 3,000 r.p.m. It appears that a slight leak is generally necessary for satisfactory operation, for with no leakage the friction torque rises to many times that when a slight leak is allowed, and constant retightening is needed to prevent the leak restarting. The test rigs are equipped to study the effects of shaft whip and shaft eccentricity.

To study the performance of centrifugal pumps a transparent test rig is under construction consisting of a glass pump casing and a Perspex impeller and suction pipe. Work is also in progress on reciprocating-pump performance and on pipe friction.

An important section of the Association's activities is the Bulletin and information service which is available to members. A selective choice of references to and abstracts from articles of technical importance in the world press is published in the Bulletin, and translations are made of articles of first importance. The information service helps members with particular technical problems brought to the Association. When a query is thought to be of general interest and a satisfactory or interesting solution has been found a Technical Note is written on the subject and made available to members.

We are greatly indebted to Dr. A. Ivanoff, Ph.D., M.Sc., M.Inst. Pet., the Chairman of Council, for permission to visit the laboratory and publish this article, and our best thanks are due to Mr. L. E. Prosser, A.K.C., B.Sc., M.I.Mech.E., the Director of Research, and to his staff, for their kind reception and for the information on which this article has been based.

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hydraulic conditions to a degree of accuracy which it may not be possible to attain in practice. It follows that venturi flume meters working under drowned conditions are more susceptible to errors.

The problem of demonstrating the accuracy of open-channel meters of the weir and venturi-flume type is not quite so easy as in the case of differential-pressure flow meters. As indicated in the foregoing, it is possible to predict, with a high degree of accuracy, the discharge coefficient of a differential-pressure meter by the volumetric calibration of a scale model. In the case of a weir or venturi flume, it may be shown that in a model test it is necessary to satisfy simultaneously both Reynolds Number and Froude's Number, the latter being a non-dimensional quantity equal to:

$$\frac{\text{velocity squared}}{\text{acceleration due to gravity} \times \text{a linear dimension}}$$

Although a complete answer to this problem defies solution, various model-testing relationships are used. For example, it has been suggested that a non-dimensional quantity, which has been called the Boussinesq Number, should be used. Denoting this number by B, depth of flow by H and width by W,

$B = F\sqrt{\frac{H}{W}} + 0{\cdot}5$, where F is Froude's Number.

In view of model-testing difficulties, manufacturers of this type of equipment over the last quarter of a century have laboriously accumulated practical data relating model tests to full-scale volumetric calibrations. Full-scale tests are a difficult and costly matter, and at times the only possibility is to check against some other form of metering device, e.g. a venturi flume against a weir or pitot-tube traverse. Therefore, it is not surprising that there is very little published literature on the subject, but there is no doubt that sufficient practical experience has been accumulated to enable manufacturers to design venturi flumes and weirs with a definite guarantee of commercial accuracy.

In theory, to measure the head over a weir or the depth of flow in the upstream of a venturi flume, it is only necessary to construct a pit adjacent to the channel, connect it to the upstream and locate the instrument float in this pit. In practice, a float chamber of this description is not particularly satisfactory, since it is not possible to check the zero setting of the instrument. It is strongly recommended that the float chamber is constructed inside a dry pit, the float chamber being connected to the channel through a pipe containing an isolating valve, and being fitted with a drain valve. In addition, the float chamber should be provided with a gauge glass and pointer set, by direct measurement, at zero level. With this arrangement, a zero check can be carried out at any time. Of course, means for draining the dry pit should also be provided. The extra expense involved is well repaid by a consistently high standard of accurate recording.

Discharge Regulators. A folding leaflet published by The English Electric Co. Ltd. describes this company's design of streamline diffusing discharge regulator. It is of the cylindrical balanced type, and can be arranged for operation either by hand or by hydraulic means. It is claimed to render channel erosion impossible at all openings, to be easily dismantled, and to involve low initial and maintenance costs.

Imperial College of Science and Technology. The forty-fourth annual report of the governing body of the Imperial College gives an account of the progress made during the year ending July 31, 1951.

Hydro-Electric Power in Peru and Chile

A brief account based on a series of articles by M. Pieyre in Revue Générale de l' Hydraulique.*

IN Peru conditions for the setting up of water-power installations are exceedingly difficult, particularly in the districts west of the Andes which happen to have the most urgent requirements. High-head plants are practically out of the question, and it is almost impossible to utilise the lakes, which are generally small and shallow and lie in most instances at altitudes reaching 16,000 to 18,000 ft. In view of such adverse conditions it seems rather paradoxical that in 1942, out of an aggregate installed power of 220,000 kW, the share of water power was no less than 145,000 kW or 66 per cent., divided into 215 plants of which no more than 15 exceeded 1,000 kW each.

In recent years, especially after the war, Peru has been endeavouring to increase its overall power production by harnessing new sources of hydraulic energy, special attention being paid to the Santa basin. By developing the most favourable sites, it is estimated that 22 plants could be set up on the Santa river with a total power of 255,000 kW. The first large-size plant is now under construction at the entrance of the Pato canyon, and an ultimate installed power of 150,000 kW (six 25,000 kW generating sets) is contemplated. In addition, further installations totalling 600,000 kW are planned on the lower Santa, and it is expected that this development will enable the port of Chimbote, at the mouth of the Santa, to become the main industrial centre of Peru. Further important plants are to be set up on the Marañon (3,000,000 kW), Mantaro (twenty 50,000 h.p. turbines), and Urubamba (120,000 kW). It is expected that this huge programme of hydro-electric development will, once completed, contribute in a high degree to the general industrialisation of a country which, heretofore, drew its national wealth almost exclusively from mining.

This survey was written before the terrible disaster of October, 1950, when, following the collapse of huge walls of ice, the water of a morainal reservoir was hurled from a height of 15,750 ft. to the bottom of the Quebrada, which flows into the Santa at the entrance of the canyon. In the canyon itself the Santa rose 165 ft., causing extensive devastation and destroying all bridges downstream.

Chile enjoys much more favourable conditions than Peru and lends itself to the setting up of practically all types of water power plants, according to the topography of the region. In view of the total absence of oil in the country and of its meagre resources of coal, it is difficult to understand why Chile was so late in becoming water-power conscious. After having laid down a most comprehensive plan of electrification in 1943, the Government-controlled "Corporacion de Fomento de la Produccion" organised a year later the "Endesa" (Empresa Nacional de Electrificacion, S.A.) for the purpose of planning, carrying into execution and operating a vast programme of development.

According to the water-power resources, industrial development possibilities, irrigation and energy requirements, the country has been divided into seven regions, of which the five northern and central regions are estimated to have an aggregate generation capacity of 6,000,000 kW; possibilities in the two southern sections have not yet been investigated but are roughly assessed at about 5,000,000 kW. Conditions vary, of course, widely from one region to the other. The general plan of development is to be carried into effect in three stages: the first one, divided into two periods (1944-54, and 1954-60) and now in progress, comprises the hydro-electric development of each region independently; interconnection of the various regional systems will be effected at the second stage, while the final stage will be devoted to the most efficient and economical co-ordination of all installations under a central board of management.

In the northernmost region (Arica-Vallenar), energy will be supplied almost exclusively by thermal plants. The second region (Coquimbo-Salamanca) presents but one unquestionable advantage, *viz.* the wide difference in level between the Cordilleras and the sea, but the hydro-electric development of this region will prove very difficult. The third and fourth regions correspond to the richest zone of the country, economically speaking, and include the Central Valley. Once completed, the energy generating equipment of this region will comprise 15 hydro-electric and seven thermal plants. The fifth region covers the wide glacial zone south of Temuco and, owing to abundant precipitations and other favourable conditions, will undoubtedly prove very easy to develop. This region was the first to be provided with a large-size plant, at Pilmaiquen (head 32 m., flow 130 cu. m./sec.), with an installed capacity of 35,000 kW. From an initial production of 13 million kWh in 1945 this plant rose to 33 million kWh in 1947.

In the fourth region we find the Abanico plant, a typical high-head plant (147 m.) with a flow of 90 cu. m. per sec., on the Rio Laja, which is expected to become in the long run the most important source of water power in Chile.

With the Sauzal plant, we enter the third region, the economically most active and most thickly populated zone of the country, including Valparaiso, the capital and most important port. Chilean hydraulic engineers are devoting their main attention to this region, which unites all the conditions required to become the most important of all from the aspect of power development. The Chileans already speak of a "Sauzal System" in which the essential aim is to

* Vol. 16. No. 59, p. 227 and No. 60, p. 292.

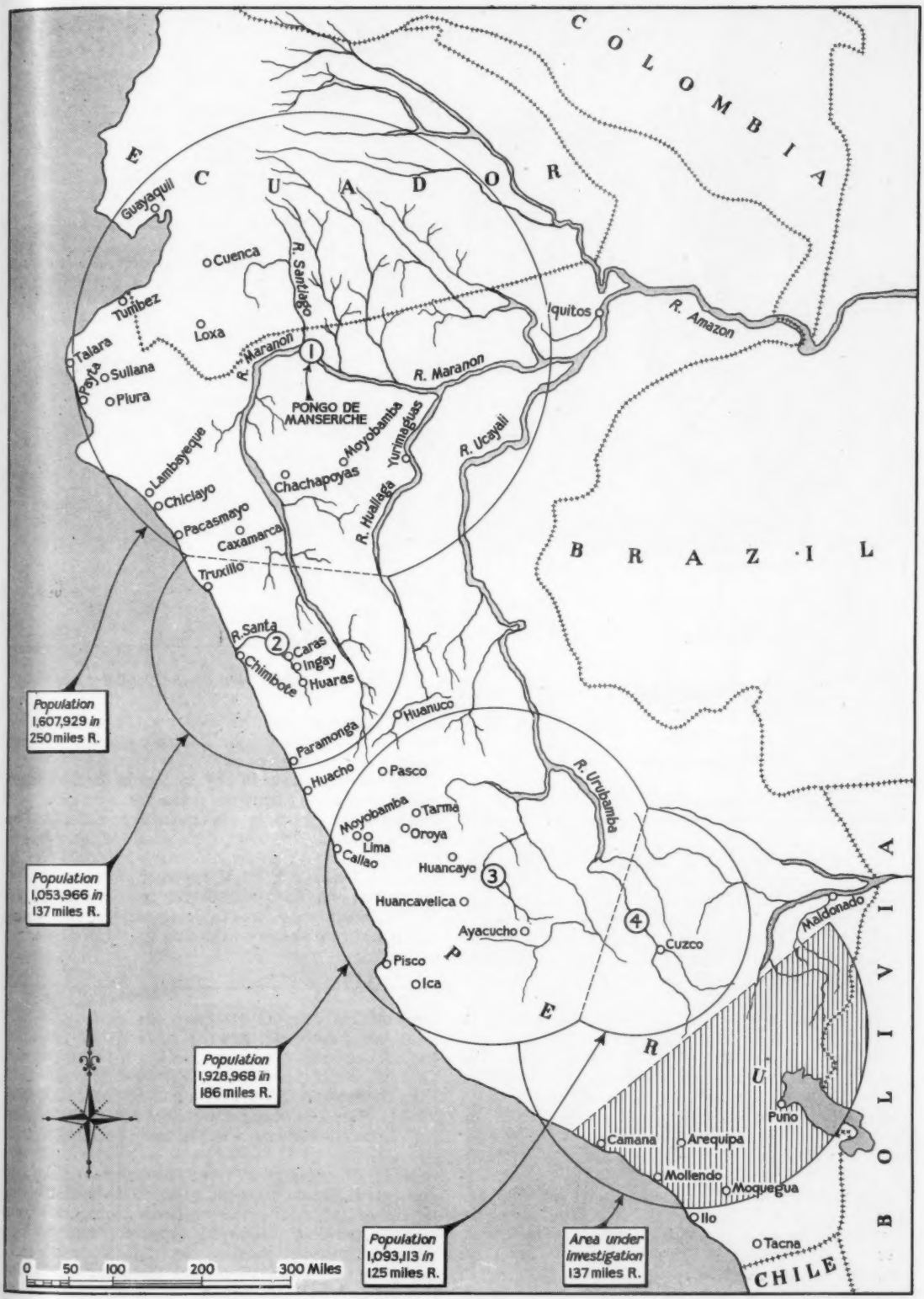


Fig. 1. Peru, showing zones of hydro-electric development

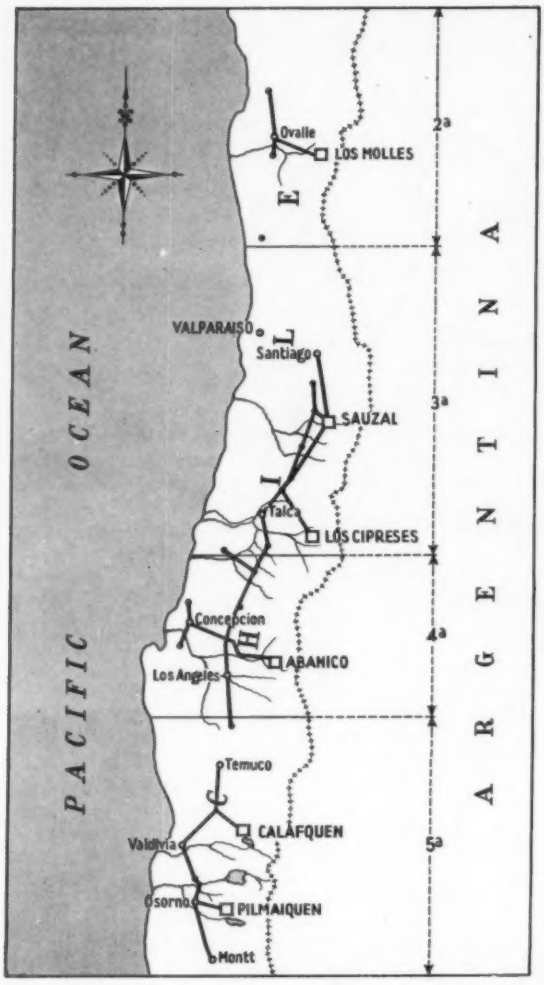


Fig. 2. Water-power regions in Chile

operate the Sauzal plant as the most important element of a wide system of connections and transmission lines (89 km. of lines at 110,000 V., 205 km. at 66,000 V, not to mention 75 km. of rural lines at 13,800 V already in operation and an extensive network in course of construction).

The Sauzal plant is to be interconnected with a plant erected on the Los Cipreses river, a tributary of the upper Maule, near Talca. This plant utilises the water of a glacial lake, the Invernada, at a height of 1,300 m., whose level will be raised by a 45 m. high dam which will afford a storage of 112 million cu. m. The Cipreses plant, when completed, will generate 108,000 kW, and is expected to be put into operation in 1953.

Further important plants are in course of completion, such as Los Molles, and Calafquén, the former set up on a tributary of the Grande-Limari, near Ovalle, and the latter utilising the water of the magnificent glacial lake of the same name, until recently practically unknown. The Calafquén plant is of the large storage type, with its power house built at the foot of the dam. Two dams will close the ends

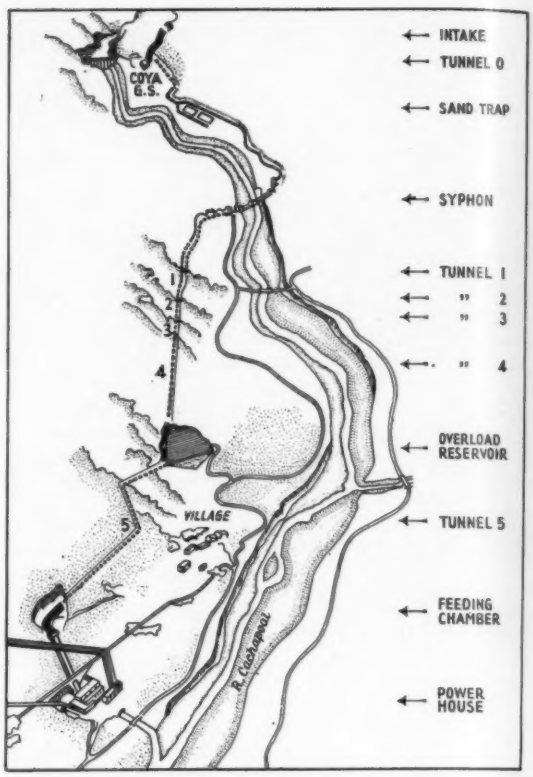


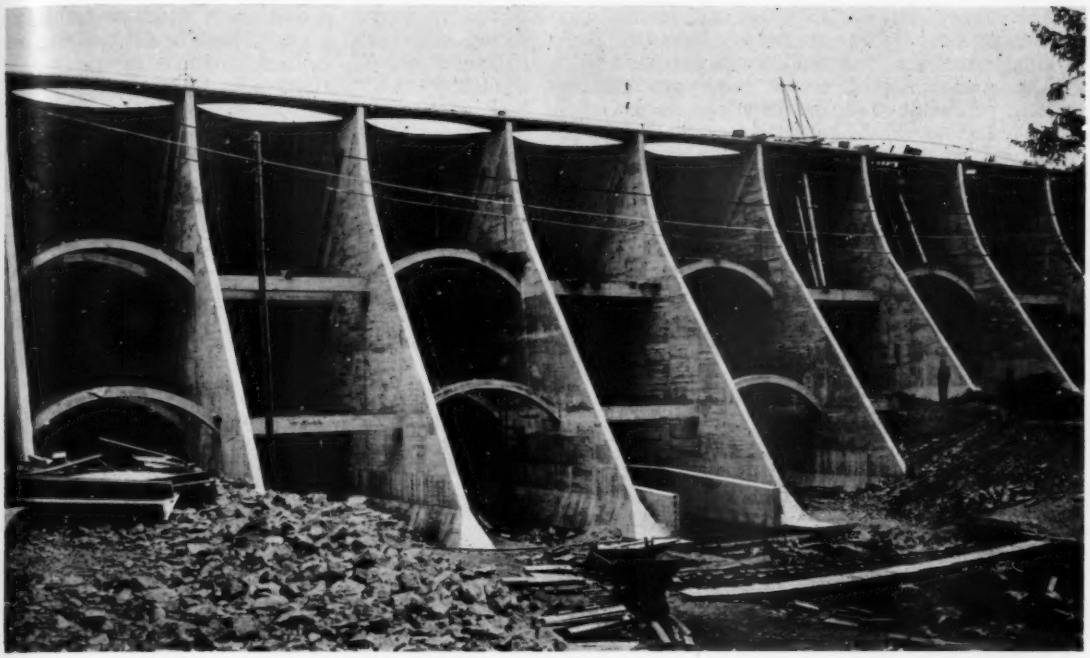
Fig. 3. General plan of the Sauzal plant

of the lake and raise its level by 138 m. minimum and 144 m. maximum; the available storage will then reach 1,200 million cu. m.

The extensive transmission system in the four intermediate regions between the northernmost and southernmost zones is particularly remarkable: we find here about 400 km. of lines at 154,000 V., 200 km. at 110,000 V, about 1,500 km. at 66,000 V, and over 400 km. at 13,200 V, together with six 154,000 V sub-stations, four 110,000 V, and fifty-six 66,000 V. These are most creditable figures for a country which has just begun to develop its water-power resources.

Grinder and Forging Hammer for Drills. Holman Bros., of Camborne, have published two coloured leaflets descriptive, respectively, of their Holbit Grinder (Publication No. HB/1099/51) and D.G. Forging Hammer (Publication No. DS/2001/51). Both leaflets give specifications of the machines, including capacities, dimensions, weights, and operating details.

Welding Electrodes for Pipes. The Quasi-Arc Co. Ltd. have published an eight-page technical circular giving details of the mechanical properties, chemical composition, welding technique, deposition and packing data of their pipe-welding electrodes, one of these being for mild-steel pipes and the other containing 0·5 per cent. of molybdenum for the effective welding of molybdenum and chromium steels as used for high-pressure pipelines.



The Faux-La-Montagne Dam

A note on a dam of unusual construction is contributed by Dr. Charles Jaeger

AT a recent meeting of the Institution of Civil Engineers, London, the dam of Faux-la-Montagne, built by Electricité de France in the French Massif Central, was mentioned. The following data may be of interest.

This dam is part of the Peyrat-le-Château development, which diverts the river Vienne at level 745·30 m. into the storage basin of Vassivières on the river Maulde (volume of storage 107,000,000 cu. m.). A 253·00 m. drop leads to the Maulde again, which describes a large loop of about 20 km. An underground power station is equipped with three 21,000 kVA sets, with total discharge of 27 cu. m. per sec. The average annual output will be 100,000,000 kWh.

The Faux-la-Montagne dam is a small dam on one of the tributaries of the Vienne at level 705·5 m. with storage feeding a small intermediary power station (3,000 kVA at 35·50 m. head). This dam is a thin multiple arch dam, similar to, but larger than, the dam of les Marécottes, built some 25 years ago in Switzerland by M. Sarrazin.

The height of the dam is 16 m.
The length of the dam is 130 m.
Width of arches 6·12 m.
Distance between buttress axes 6·40 m.
Thickness of arches at base 0·14 m.
Thickness of arches at crest 0·08 m.

(Continued overleaf)

Thickness of buttresses 0·28 m. with enlargement at the base.

Gradient of the upstream dam face 1 : 0·75.

The steel-reinforced arches were concreted by cement gun without any working joint in the whole height of the arches. Shutters were used on the internal side of the arches only, as can be seen in the accompanying photographs. The lateral stiffening with arched struts is well worth mentioning, the idea being to give the greatest possible elasticity to the whole structure. This multiple arch dam was designed by Etudes et Entreprises S.A., Toulouse.

Recent papers published by engineers of Electricité de France show that it is their deliberate policy to investigate new types of light structures in order to obtain the maximum of economy.

Sron Mor Power Storage Scheme

H. H. Anderson gives a brief account of the tests on a one-fifth-scale model pump-turbine-motor-induction-generator unit recently constructed by the Harland Engineering Co. Ltd. in connection with this scheme

A DISADVANTAGE of alternating current is that power cannot be stored. On small direct-current schemes battery storage is possible, but modern power stations must generate electricity the instant it is required.

Attention is now being given to the possibility of raising water to an upper reservoir as a means of storing power. This permits the use of cheaper power at off-peak periods, for example, at night, for pumping water which can be returned to provide valuable power at peak times. The economics of this scheme depend on the difference in value of an electrical unit on peak and off peak.

The first large power storage scheme under construction in Britain is the Sron Mor station situated at 970 ft. and pumping to a higher reservoir at 1,118 ft. above sea level. This station offers two advantages: (a) pumping water to the upper level when rainfall is in excess of the capacity of the larger power station at sea level, thus avoiding the loss of power that would occur with overflow at the 970 ft. spillway, and (b) transfer of peak load from day to night.

The Sron Mor station comprises a turbine, a motor/induction generator and a pump, all on the same shaft. The pump idles during turbine operation and the turbine idles during pump operation, the electrical unit working in turn as induction generator or as induction motor. The idling unit is kept free from water by compressed air.

This pump, of 7,000 h.p., will deliver 130,000 g.p.m. against a head of 150 ft., but is also capable of operating over the head range of 100 to 160 ft. The pump will be larger in size than the Harland turbines at Grudie Bridge and will have a 90 in. stainless-steel impeller. As such a unit is far too large for a works test, a model to one-fifth scale has been made and tested, and a view of the unit on the testbed is given herewith.

The test is carried out at five times the speed of the full-size unit so that homologous performance in respect of head, velocities and stresses is obtained. It is then possible to apply a correction factor to the efficiency based upon the change of Reynolds number of model to full size. The model test showed very promising results, agreeing closely with the tender curve. The pump required very special characteristics so as to operate over the wide range of head from 100 to 160 ft. with good efficiency and without risk of cavitation.

The guaranteed efficiency of the full-size unit is 88 per cent. and the model efficiency scaled up to the final pump was 89 per cent.

On an emergency failure of power, the pump would lose speed, the water column would stop and reverse, thus braking the pump and finally driving it in re-

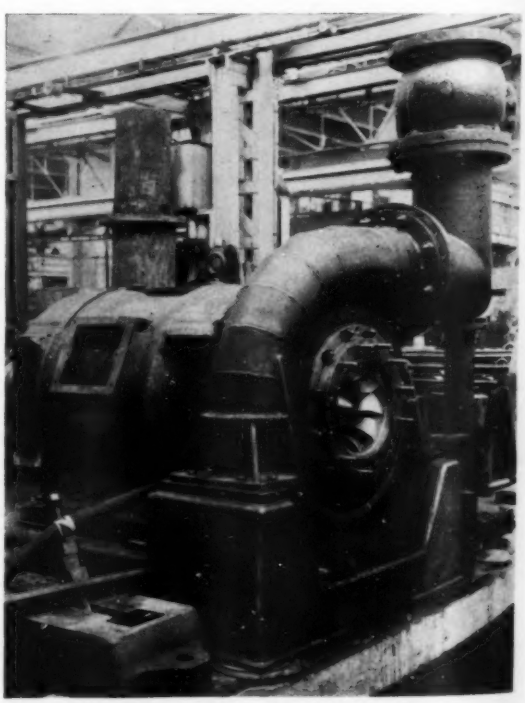


Fig. 1. The one-fifth scale model of the Sron Mor unit on the testbed at the Harland works

verse as a turbine. It is necessary, therefore, to determine the performance of the unit as a turbine with no load other than the windage and bearing losses of the motor so as to ensure that no mechanical damage or risk of bursting will occur at reversed rotation or overspeed.

Prior to turbine operation, the Sron Mor unit passes through an energy-destruction or braking phase. The model was, therefore, tested by driving in the normal direction while forcing water against rotation, the unit absorbing and destroying both torque, energy and water energy. It was then tested with the rotor locked to reproduce the stationary instant between positive rotation (energy destruction) and negative rotation (turbine). Finally a turbine operation test was made by permitting the pump to rotate under the influence of water fed to the "delivery branch" and taking and measuring the resulting electrical energy from the motor as an induction generator.

On normal pump systems the pipes are in general sufficiently rigid to withstand vacuum, but on a large job, for example the 9 ft. pipes of Sron Mor, the steel thickness adequate for pressure will not be adequate to withstand vacuum. It is, therefore, necessary to carry out an arithmetic integration, which is a detailed mathematical analysis measured at time intervals after power failure, of changes of head and other phenomena. In this way, we can ensure that adequate flywheel effect is built into the set to avoid too drastic reduction of speed and head which would permit vacuum conditions. In this respect it is interesting to recall that in 1914 two miles of 10 ft. pipe collapsed due to vacuum in California. The pipe was slowly refilled with water under pressure and "blown" circular again, with very little cost in the way of repairs.

Now that the tests are complete construction of the full-size unit can be commenced. This will become one of the largest and probably the most powerful pump made in the United Kingdom.

The model just described was recently shown on the stand of the Harland Engineering Co. Ltd. at the Inverness Electrical Economy Exhibition.

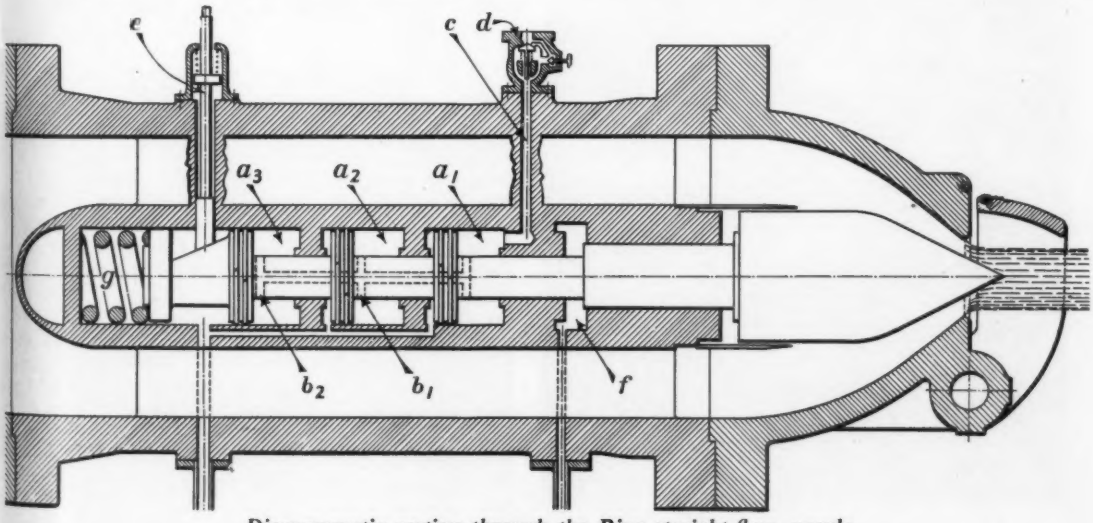
The Riva Straight-Flow Nozzle

The imperfections in the trajectory of the water jet emerging from the nozzle of an impulse turbine have long been known and are, of course, recognised as being inherent in the design of the nozzle and the nature of the connections leading up to it. These irregularities are caused by the different speeds at which the water emerges from the nozzle as a result of the curved lead-in, and which is required to permit the regulating needle to be accommodated in such a way that its extremities can be conveniently linked with the governing mechanism.

With the view to eliminating the defects which occur as a result of this arrangement, the Riva Company of Milan began to work in 1942 on the idea of designing a straight-flow nozzle without the conventional leading-in bend. To this end the operating mechanism of the piston rod carrying the nozzle has been mounted concentrically within the nozzle body, the design being covered by a patent (Riva-Battistin No. 421631).

With this arrangement it is claimed that the entire transverse section of the water flow through the nozzle and lead-in travels with a velocity that is rigorously uniform, and this condition holds good for the full length along the narrowing approach to the nozzle. Consequently, the speed of the jet itself as it leaves the nozzle is also uniform, as disturbances due to centrifugal action and differential frictional forces have been eliminated.

The Riva nozzle consists of an outer body and a concentrically mounted inner cylinder which houses the needle operating mechanism, the annular space between them providing a path for the hydraulic flow. This central component is supported by two solid cross-pieces which have been carefully designed to



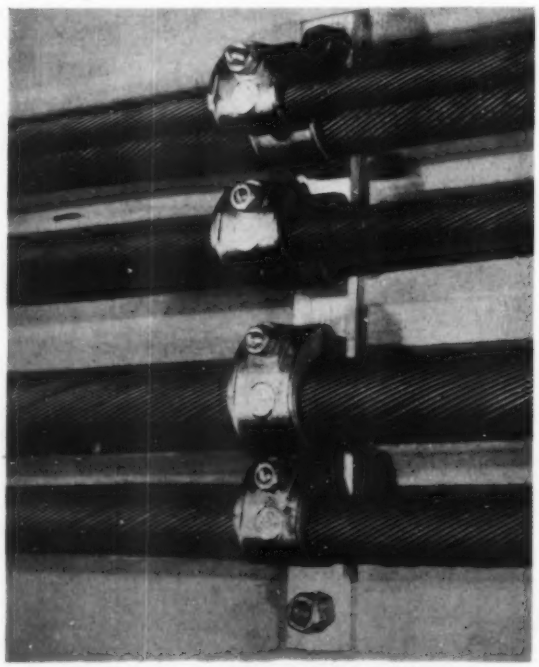
Diagrammatic section through the Riva straight-flow nozzle

secure a correct hydraulic profile. The inner cylinder contains a triple piston mounted on a rod which carried the needle at its forward end. Referring to the accompanying diagram, oil pressure under the control of the speed governor is conveyed to the chambers a_1, a_2, a_3 of the servomotor through the pipe c and its interconnections b_1 and b_2. The pressures exerted on the faces of the pistons provide a force which overcomes the combined forces exerted by the spring g and the hydraulic closing tendency of the needle, thus moving the needle away from the orifice. To obtain the reverse movement it is sufficient to open the pipe c to the discharge position, the action of the spring, added to the retreating force exerted on the needle by the closing pressure of the water, causing the needle to approach the orifice. The rate of this motion is controlled by a throttling valve d in pipe c. In this way the servomotor acts as a brake during the closing movement. Chamber f collects and discharges any leakage of water or oil that may pass through the glands.

We understand that equipment of this type has been fitted to impulse turbines having an aggregate of 1,000,000 h.p., if plant actually under construction is taken into consideration. Industrial units have been constructed of over 100,000 h.p. and for operating heads of up to 1,200 m. (3,940 ft.).

Claw-type Cable-Cleating System

To satisfy the need for a universal assembly that can be easily built up, modified or adapted on site to any particular arrangement or rearrangement of cables, British Insulated Callender's Cables Limited have introduced a claw-type cable-cleating system. The salient features of this will be apparent from the accompanying illustration.



B.I.C.C. claw-type cable-cleating system

The cleats can be used singly or in groups mounted on suitable backstraps, and they are easily fixed to walls or steelwork for horizontal or vertical runs.

Suitable for all types of cable sheathed with lead, aluminium or other material—bare, served or armoured, they can be installed in any normal indoor or outdoor situation. The alloy used is resistant to corrosion, and the oxide film, which always forms on exposed aluminium, provides further protection. Direct contact with copper or copper-bearing metals should, however, be avoided and for excessively damp or corrosive atmospheric conditions, a special finish can be provided

A comprehensive range of cleats, studs and wall bolts is available, the different sizes being all interchangeable so that there need be no wastage or scrap, and requiring but a minimum stock of parts.

Cleats consist of two identical halves, die-cast in a magnesium-free silicon-aluminium alloy conforming to B.S.702 : 1936 and chosen specially for its strength, lightness and resistance to corrosion. For cables up to 2 in. (51 mm.) a single-bolt fixing is used, giving maximum accessibility. The cleats cannot rotate on the backstrap when the fixing bolt is tightened and the two halves are dowelled together to ensure their correct alignment and the proper clamping of the cable. Cleats for cables exceeding 2 in. diameter have a two-bolt fixing. Each cleat is clearly marked with the range of cable diameters that can be accommodated.

Backstraps are of galvanised mild steel drilled and tapped $\frac{3}{8}$-in. Whitworth for cleat fixing studs. A clearance hole for a $\frac{1}{2}$-in. fixing bolt is provided at each end.

Cleat-fixing studs are of spun-galvanised steel, screwed $\frac{3}{8}$-in. Whitworth and complete with one nut. A suitable tool is available for inserting or removing studs.

Indented wall bolts, or if preferred expansion-type bolts, are supplied for fixing backstraps or single cleats to brickwork, concrete chases or masonry. Wall bolts are of spun-galvanised mild steel, the indentations ensuring a secure fixing after grouting, with a minimum of cutting away. Expansion-type bolts require no grouting. For fixing to steelwork, standard hexagon-headed galvanised bolts are suitable.

Red-Lead Primer for Wetted Surfaces

The value of ordinary red lead as an anti-corrosive rust-inhibiting primer is well known. However, where it is intended to protect constructions exposed to water with bituminous solutions it is necessary to wait for months on end until the primer coat dries and hardens completely—a delay which rules it out for repair and maintenance work and limits its use on new work. Furthermore it cannot be used as undercoat for chlorinated-rubber paints because the solvents used act like paint stripper. Again, chlorinated-rubber red-lead primers nullify the corrosion-inhibiting qualities of the red lead, bleed through subsequent coatings, and can in any case carry no more than about 20 per cent. of red lead—an insufficient amount. The problems of these deterring factors have engaged the attention of Evode Limited, of Stafford, who are offering under the brand-name "Evo-Led" an entirely new type of red-lead primer suitable for application to damp or even wet surfaces, which, they claim, is

non-lifting or bleeding after 24-48 hours—even when overpainted with paints containing searching solvents.

"Evo-Led" primer is stated to displace moisture on any surface, and to absorb it and allow it to evaporate together with the solvents during the drying processes, the result being a perfect bond. One gallon of "Evo-Led" primer will cover between 35 and 50 square yards of surface.

Vickers VR. 180 Tractor

A recent announcement by Jack Olding & Co. Ltd. intimated that the production of the VR. 180 Tractor would begin in March this year, the prototypes and pre-production models having now undergone the most exacting tests to the complete satisfaction of the designers. It is hoped that this machine, which is powered by a 180 h.p. Rolls Royce oil engine, will help to meet world demand for faster and more efficient earth moving tractors of the heavier type and will thus make a valuable contribution to an export trade.

It is understood that both the tractor and ancillary equipment will be on view at the forthcoming British Industries Fair at Birmingham and in the meantime Jack Olding & Co. Ltd., the distributors, have issued a handsome coloured brochure dealing with the design and specification, performance data and constructional details. Our two illustrations show respectively the tractor at work with a cable-operated dozer and with a VS. 180 scraper.

Fig. 1. Vickers VR. 180 tractor operating with VS. 180 scraper

Fig. 2. The tractor with cable-operated dozer

Holbit Grinder

The Holbit grinder, type ABG, offered by Holman Bros. Ltd., has been developed in conjunction with the Abwood Tool Engineering Company. Two grinding wheels are fitted, one at each end of the spindle. One is for redressing the gauge of both cross and chisel bits. The other is for redressing the cutting edge for cross-type bits, and a grinding wheel, face "K," dressed to a double bevel of 40° is necessary. This wheel can also be used for chisel bits, but if chisel bits only are being used a flat-faced wheel can be used. Mandrels can be supplied for all sizes and types of Holbits.

The workhead spindle is arranged to take a 3 in. chuck. This enables the grinder to be utilised for other general grinding purposes if desired.

The main spindle is of high-tensile steel and is equipped with adjustable taper-roller main bearings, which are sealed against the entry of grinding dust or coolant, and are grease-gun lubricated.

The main motor has a 2 h.p. rating and a spindle speed of 1,742 r.p.m. It is a reversing flange-mounted type built completely into the body of the machine.

It is essential that silicon carbide (green grit) wheels be used for redressing Holbits. The wheels recommended and supplied are Carborundum GC60-K5-VG. If wheels of any other make be employed, they should be of the same grit and grade.

Abstracts from the World Technical Press

New Sand Trap Designs

Most of the usual types of sand traps at present in operation are characterised by their great length and considerable depth, the latter being particularly unfavourable to the correct settling of the sand particles. When comparing the settling of sand in a vertical and in an inclined glass tube it can be seen that it occurs much more quickly in the latter than in the former. This led to the conclusion that sand trapping can be improved by the insertion of inclined baffles between which water can move vertically or horizontally; the main disadvantage of this multicellular type of sand trap lies in the difficulty in collecting the sand deposited on the baffles and transferring it to the conveying arrangement which will carry it away. The author subsequently worked out several sand trap designs which can be divided into three different types, viz., (1) multitubular type; (2) flat-cell type with upward flow; (3) multicellular type with horizontal flow.

Fig. 1 shows a multitubular sand trap in which the sand-carrying water flows upwards; the trapped sand deposits in the vicinity of the lower portion of each tube, glides downwards and drops into a watertight casing enclosing the nest of tubes, collecting subsequently in a gathering vessel. This arrangement permits the sand to be trapped without substantial loss of water. Very good results are achieved with tubes varying between 10 and 2 cm. in width, and in length between 5 and 2 m., even in the case of particles 0·2 mm. in diameter moving at a speed of 50 cm. per sec. This type of sand trap may prove useful in certain branches of industry but would involve considerable expenditure in connection with large hydro-electric schemes.

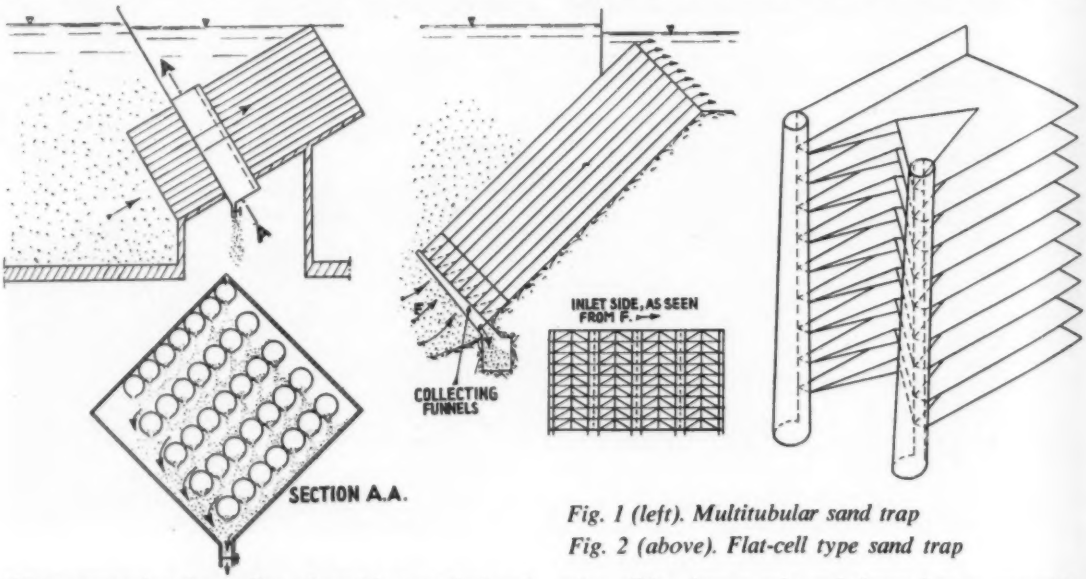


Fig. 1 (left). Multitubular sand trap
Fig. 2 (above). Flat-cell type sand trap

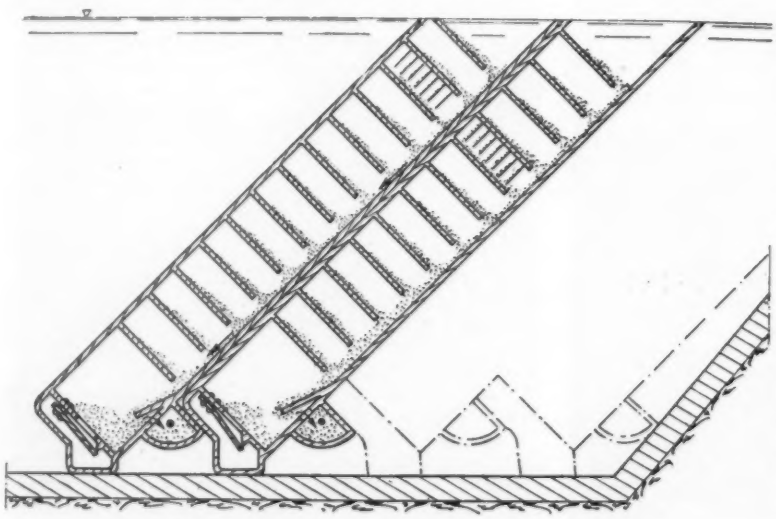


Fig. 3. Improved horizontal-flow sand trap

In the flat-cell type sand trap parallel flat or corrugated plates form the cells. A simplified design of this type is shown in Fig. 2; here the inlet ends of the plates are provided with bulges which guide the sand towards funnels connecting with collecting channels at the bottom of the trap. This type of sand trap proved very

efficient, but owing to the relatively large space required endeavours were made to work out an improved design. This is shown in Fig. 3, the cells being arranged parallel with the side walls of a channel of trapezoidal cross section. The sand-carrying water passes through the cells in a horizontal flow, the sand deposits on the plates and, following the line of the steepest gradient, collects at the bottom of each cell while the purified water leaves at the downstream end.

Calculation with a view to determining the correct settling and collecting of the sand is quite simple when dealing with laminar flow but much more complicated in the case of turbulent flow. By means of a simplified calculation the author shows, however, that the total space occupied by compartment-type sand traps is substantially less than for traps of the usual type. The weight of the steel plates necessary to the control of a given discharge is a function of the falling velocity of the particles to be separated and of the slope of the baffles.

It would appear in many instances that sand traps of small size could effectively be used to prevent the passage of much smaller particles than can be trapped with the usual type of apparatus, and could be widely applied. (Paul Gariel, "Mémoires et Travaux de la Société Hydrotechnique de France," Vol. II, 1951, p. 176, and *La Houille Blanche*, Vol. 6, No. B, October 1951, p. 630, 10 pp., 12 ff.)

Accelerated Schedule for Cabinet Gorge

Time is the controlling factor in the construction of the $40 million Cabinet Gorge dam and power-house. The 200,000 kW of new generating capacity is badly needed and the Washington Water Power Co. wants to take advantage of fast amortization (for tax purposes) permitted by certification of the job as a defence project. An accelerated construction rate will also reduce the overall cost of the project, as well as interest charges. Of even greater importance, diversion tunnels and cofferdams need be built only for use in low-flow times of the year.

The dam is located on the Clark Fork river some 10 miles above lake Pend Oreille in northern Idaho, and will plug a narrow Z-shaped gorge; penstock and diversion tunnels pierce a rock peninsula formed by the gorge. Diversion was accomplished in August but completion of the cofferdams, dewatering the site, and excavating to bedrock held up concrete pouring until November 15; work had thus to continue through the winter so that a substantial amount of concrete will be in before the flood season begins in the spring. As aggregate must be heated, and poured concrete kept from freezing, wintertime construction was expensive, but less expensive than the diversion tunnels and cofferdams which would have had to be provided for controlling a substantial flood.

The contractors are attempting to get the dam up to el. 2,080 (about half its height) and to have the base portion of the power-house, including draught tubes, in place before the spring floods. The first generating unit is to be on the line for trial operations by September 1, 1952. It will be recalled that technical particulars of this scheme were given in an article we published in our issue of October 1951. (*Engineering News-Record*, Vol. 147, No. 24, December 13, 1951, p. 36, 3 pp., 5 ff.)

Water-hammer Upstream of the Surge Tank

In this article the authors show that when the surge tank of a hydro-electric plant is connected to the intake tunnel by a penstock of relatively small cross section, part of the pressure surge resulting from the closure of a gate or other similar device may be transmitted to the intake tunnel. Proceeding from the partial reflection and refraction of a wave reaching a branching, they investigate the action of a penstock inserted between a tunnel and a surge tank on the development of water-hammer in the intake tunnel, and give as an example the simplified case of an existing installation with the following characteristics:

Intake tunnel 1,200 m. in length, 11·5 sq. m. in cross-section; wave velocity, 1,200 m. per sec.

Penstock 120 m. in length, 8 sq. m. in cross-section; wave velocity 1,200 m. per sec.

Maximum discharge 8 cu. m. per sec. Head 100 m.

The accompanying graphs show that the fraction of pressure surge varies as a function of the cross-section ratios. In the case of quick closure, i.e. when the closing period is shorter than the phase time of the penstock ($\tau < \frac{2l}{a}$), the length of the penstock exerts an action only on the tunnel length continually affected by the maximum pressure surge, and the cross section of the penstock is in agreement with the

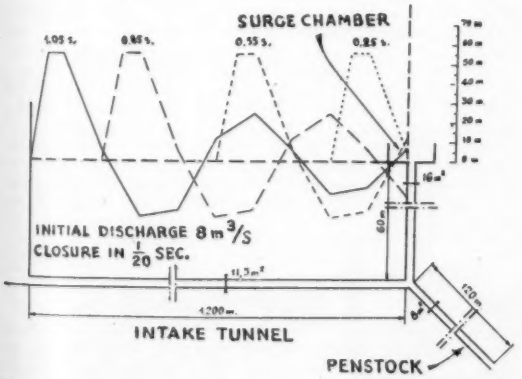


Fig. 1. Influence of cross section of penstock under quick closure

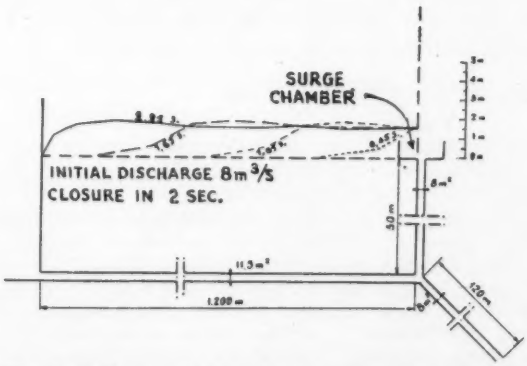
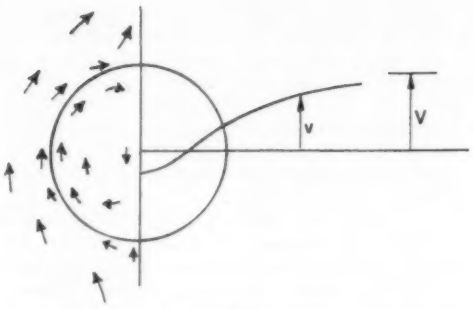
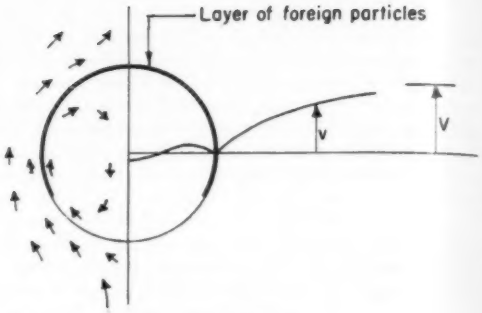


Fig. 2. Influence of length of penstock under slow closure



(a) Uncontaminated interface



(b) Partially contaminated interface

theoretical results of the graph reproduced in Fig. 1.

In cases of slow closure ($\tau > \frac{2l}{a}$) the pressure surge may be reduced by the pressure drop subsequent to the reflection of the wave at the bottom of the surge tank; in fact, it decreases with the closure period and increases with the length of the penstock (Fig. 2). If, however, the cross section of the penstock is increased the proportional decrease of the maximum pressure is greater than the decrease shown by theory, owing to the additional reflection of the water surface in the surge tank.

The influence of the length and of the cross section of the penstock are examined separately for both quick and slow closure. Surge tanks fitted at the bottom with a throttling orifice act in the same way as very short penstocks, and give rise only to a negligible additional pressure surge.

As a means of protection against very substantial pressure surges throughout the whole length of the intake tunnel, the authors advocate the addition of an auxiliary penstock connecting with the tunnel immediately downstream of the section to be protected, this auxiliary tunnel fulfilling the function of a deterrent to water-hammer.

In consideration of the fact that theoretical investigations do not throw any light on this aspect of the problem, the authors conclude that practical investigations in the intake tunnel of an existing hydro-electric plant would greatly contribute to the elucidation of this question of water-hammer development. (R. Jupillat and A. Trividic, "Mémoires et Travaux de la Société Hydrotechnique de France, Vol. II, 1951, p. 186, and *La Houille Blanche*, Vol. 6, No. B, October, 1951, p. 610, 7 pp., 12 ff.)

Particles in Slow Motion

Just a century ago Stokes presented the scientific world with his theory of the internal friction of fluids, which subsequently led to the simple equation for the motion of a sphere appropriately called Stokes' Law. Since then many research workers have investigated the motion of particles at low values of Reynolds' number. In this article the author endeavours to determine the present state of this research work, in part not hitherto published, which is likely to find interesting applications in a wide range of subjects. The author suggests the addition of a factor K to the otherwise familiar equation, which thus becomes:—

$$F = (3\pi\mu Vd)K,$$

and names this dimensionless new factor Stokes' number; he then examines the influence of various parameters on K: conditions at the boundary of the fluid area (vertical, cylindrical or plane boundary), actual shape (ellipsoid, disc) and position of the particle, and the presence of several particles. Special attention is paid to fluid spheres which have been found to move sometimes as though solid and sometimes as though fluid, the variation in surface contamination being accepted as the possible cause of this anomalous behaviour. This effect is shown in the diagrams given above. (J. S. McNown, Associate Director, Institute of Hydraulic Research, Iowa City, U.S.A., *La Houille Blanche*, Vol. 6, No. 5, September-October 1951, p. 701, 10 p.p., 7 ff., Appendix 5 pp.)

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Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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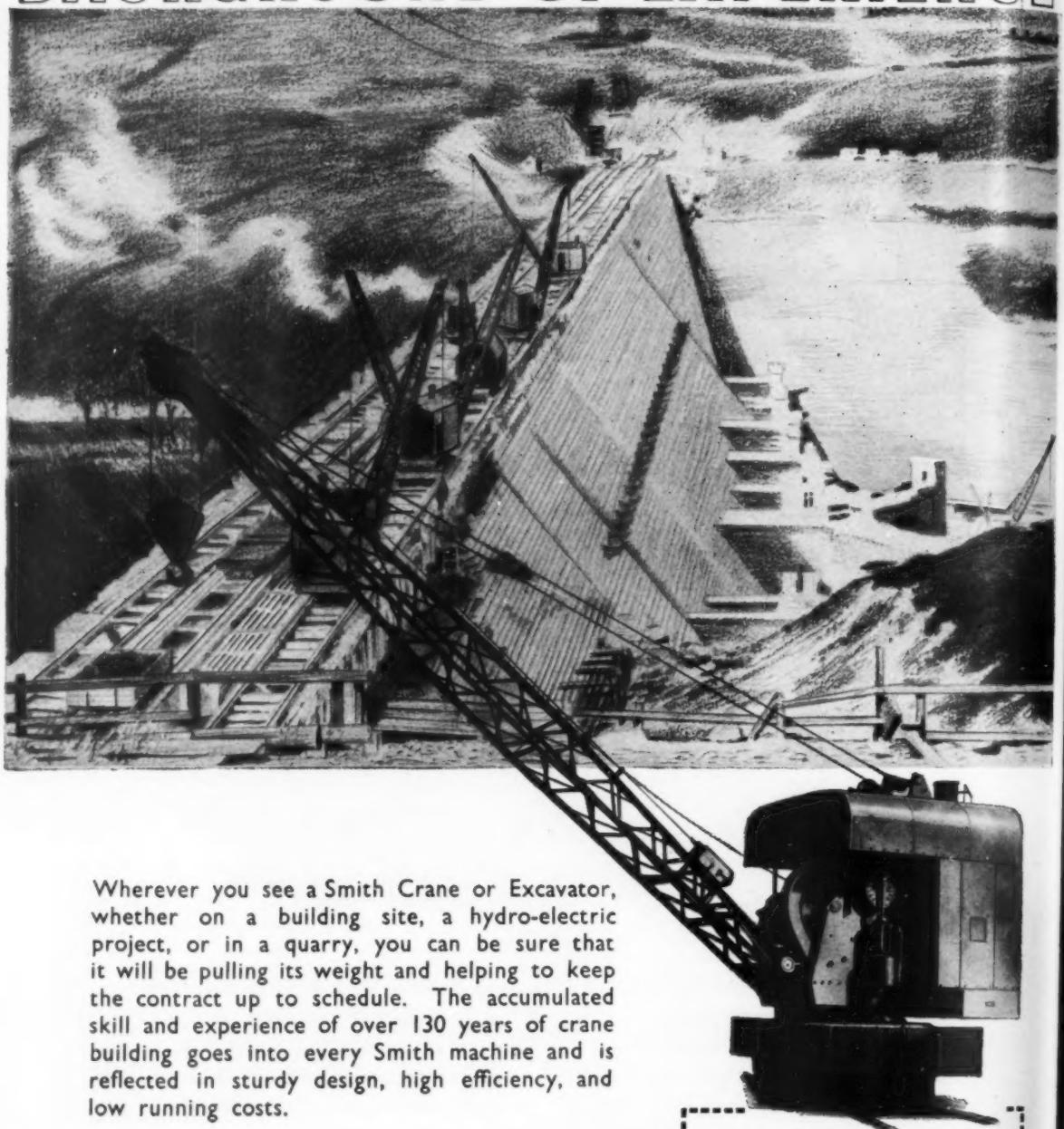

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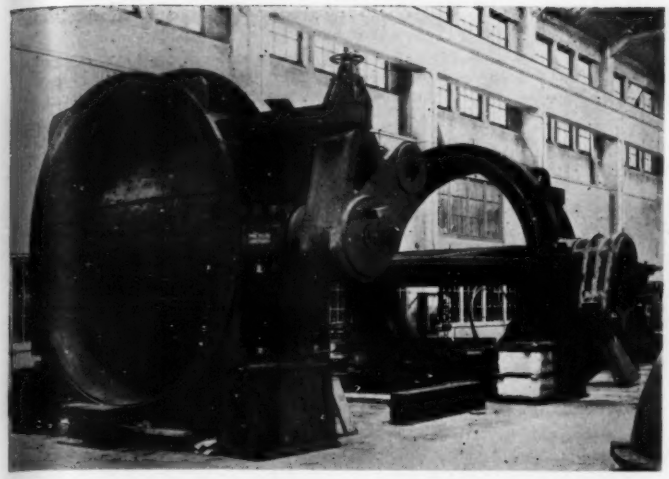

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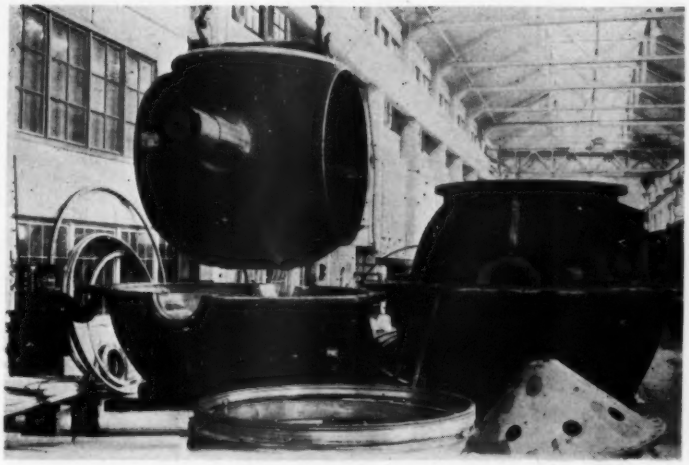
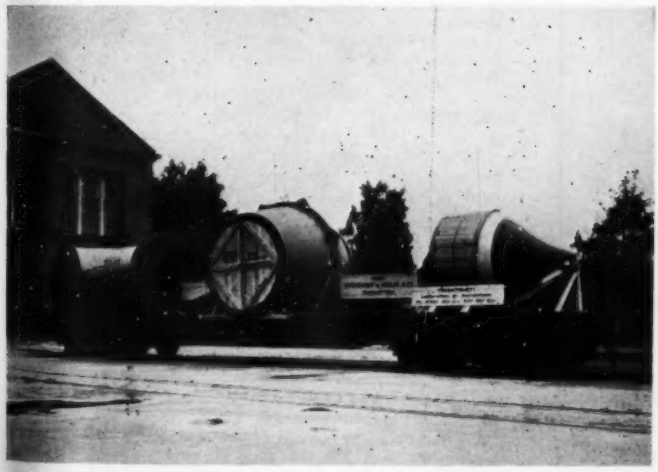


Spherical valve. Pipe diameter 1.9 m (6 ft. 3 in.)



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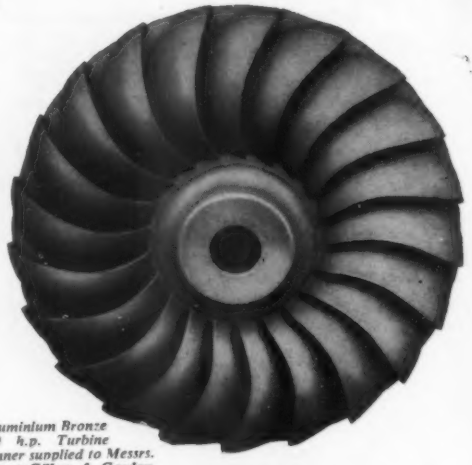

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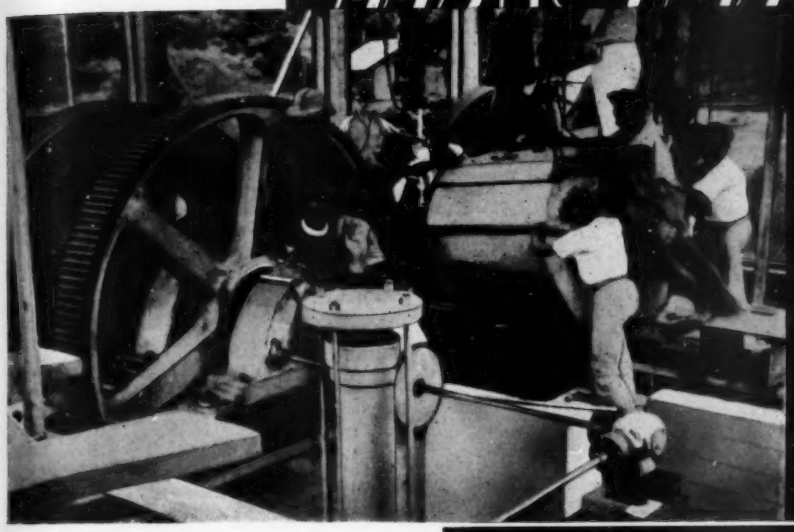

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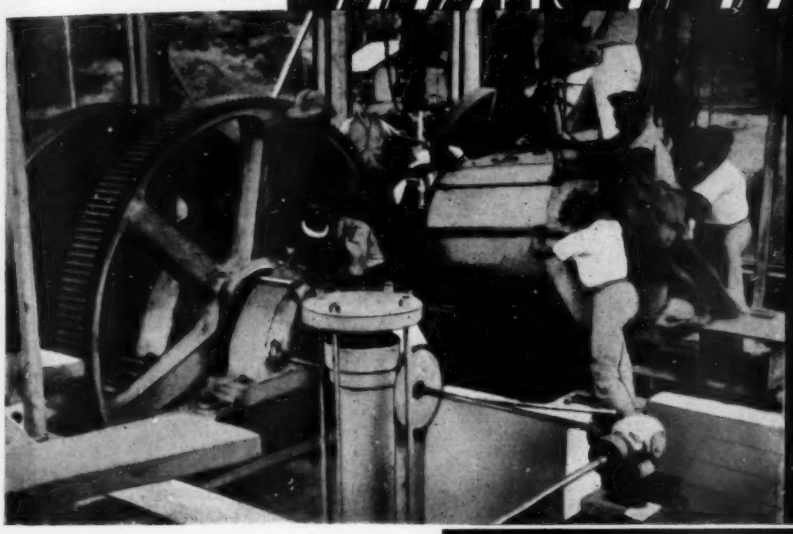

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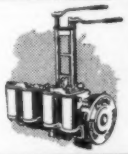

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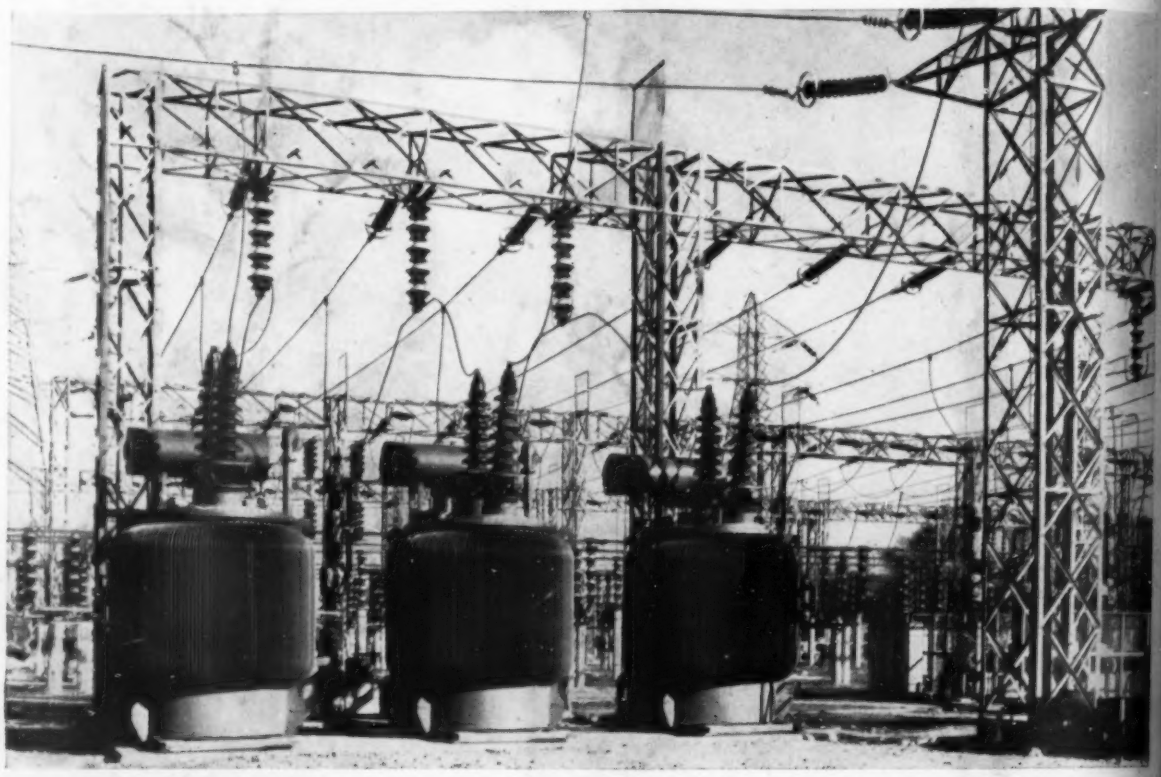

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